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ELECTRON GUN TEST REPORT

contract

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Statement of Work:

The purpose of this investigation was to determine the electron-optical properties of Machlett Laboratories Model EE 65-1 20 KeV electron gun. Also included in the program were tests to prove the design capabilities of the gun, as well as lifetime studies.

Cost and time considerations limited the extent of this investigation to two prototype electron guns.

Experimental Procedure

The experimental program involved three distinct phases:

A. Development and application of an inspection test plan.

B. Shock and vibration proof tests.

C. Open-gun studies.

Initial development of the inspection test plan was begun in August, 1970 before delivery of the prototypes. The plan was designed around an earlier procedure utilized in testing Machlett Labs type EE 65 10 KeV guns used on a previous program. The test procedure included complete mechanical inspection including a dimensional check of all critical parts. Electrical inspection involved tests for dielectric strengths, cutoff, emission, and element to element leakage resistance. All test circuits and equipment for each test was specified in the test plan. The final version of the inspection procedure is contained in appendix A (I/ML-EE65-1 Rev. 3).

Shock and vibration testing was performed according to the schedule shown in Table A. This schedule is the result of the requirements of the STRYPI IV launch vehicle requirement.

TABLE A - SHOCK & VIBRATION TEST SCHEDULE

Sinusiodal Vibration

1g 20 to 500 Hz

6g 500 to 2000 Hz

for 30 seconds all axis

Random Vibration

Frequency 20 to 2000 Hz

PSD Level 0.05 g^2/Hz

Acceleration 10 g rms

Duration 10 seconds each axis

Shock

15 g half sine, 15 milliseconds duration in both directions all axes

The procedure for shock and vibration testing was as follows:

1. Inspect gun to I/ML-EE65-1 test plan.
2. Shock and vibration to schedule in Table A.
3. Reinspect to I/ML-EE65-1.

Only one gun was tested in this manner at one time in anticipation of possible failure. The first prototype was also fully tested in the open-gun mode before the second was put through shock and vibration. Breakseal tabs were tied down according to the flight mounting configuration for purposes of the above test.

Open-gun tests were performed with the test circuit shown in Figure 1 after the breakseals were opened with the circuit indicated in Figure 2. The tests were conducted in a two-foot cube vacuum chamber utilizing a 6" oil diffusion pumping system with freon cooled baffle at -20°F and liquid nitrogen baffle. Base pressure in the aluminum chamber was about 1×10^{-6} torr for all tests. Tests conducted in the open-gun mode were those outlined in Table B.

TABLE B - OPEN GUN TESTS

Test Conditions:

1. E_F = 7.5 volts DC ± 5%.
2. E_{C1} (Bias g1 to negative HV) + 40 volts DC ± 5%.
3. E_{C2} variable 250 - 1500 VDC.
4. E_A 5.0, 10.0, and 20.0 KVDC ± 10%.
5. The gun and socket will be contained in one atmosphere of dry SF_6.
6. The first gun tested will be done in a modified EE 65 socket contained in one atm. SF_6. The second gun will be mounted in

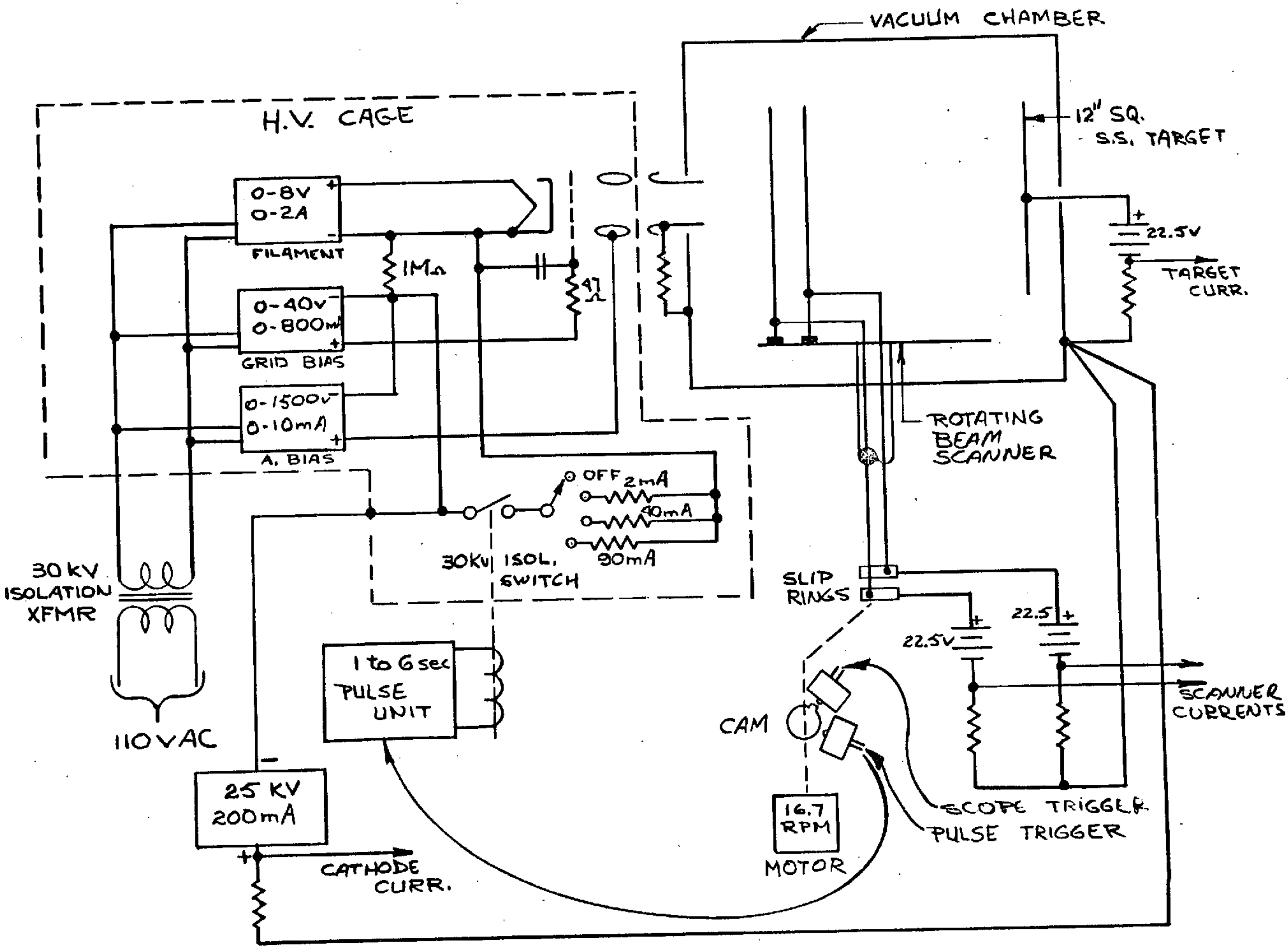
of d

socket C-1055-031 in a configuration referenced by C-1055-003 excluding the spinning with the second anode insulated from ground as in the flight pkg.

Tests Performed:

At each anode two voltages of 5, 10 and 20 KV
and each cathode current of 40 mA and 90 mA
and each anode one voltage of 250, 500, 750, 1000, 1250 and 1500 v.

1. Beam angle via Visicorder
2. Pulse shape for 1 sec and 6 sec via scope photograph
3. Long term test (at least 1 hr) at 20 kv, 100 mA, 50% duty cycle (Vc_2 = 1KV) with 6 second pulses to determine lifetime characteristics.


VACUUM CHAMBER
H.V. CAGE
12" SQ.
S.S. TARGET
0-8V
0-2A
FILAMENT
1MΩ
47 Ω
0-40V
0-800mA
GRID BIAS
0-1500V
0-10mA
A. BIAS
22.5V
TARGET CURR.
ROTATING BEAM SCANNER
OFF
2mA
40mA
90mA
30KV ISOL. SWITCH
30 KV ISOLATION XFMR
110 VAC
SLIP RINGS
22.5V
22.5
1 to 6 sec PULSE UNIT
CAM
SCANNER CURRENTS
25 KV 200mA
16.7 RPM
MOTOR
SCOPE TRIGGER
PULSE TRIGGER
CATHODE CURR.

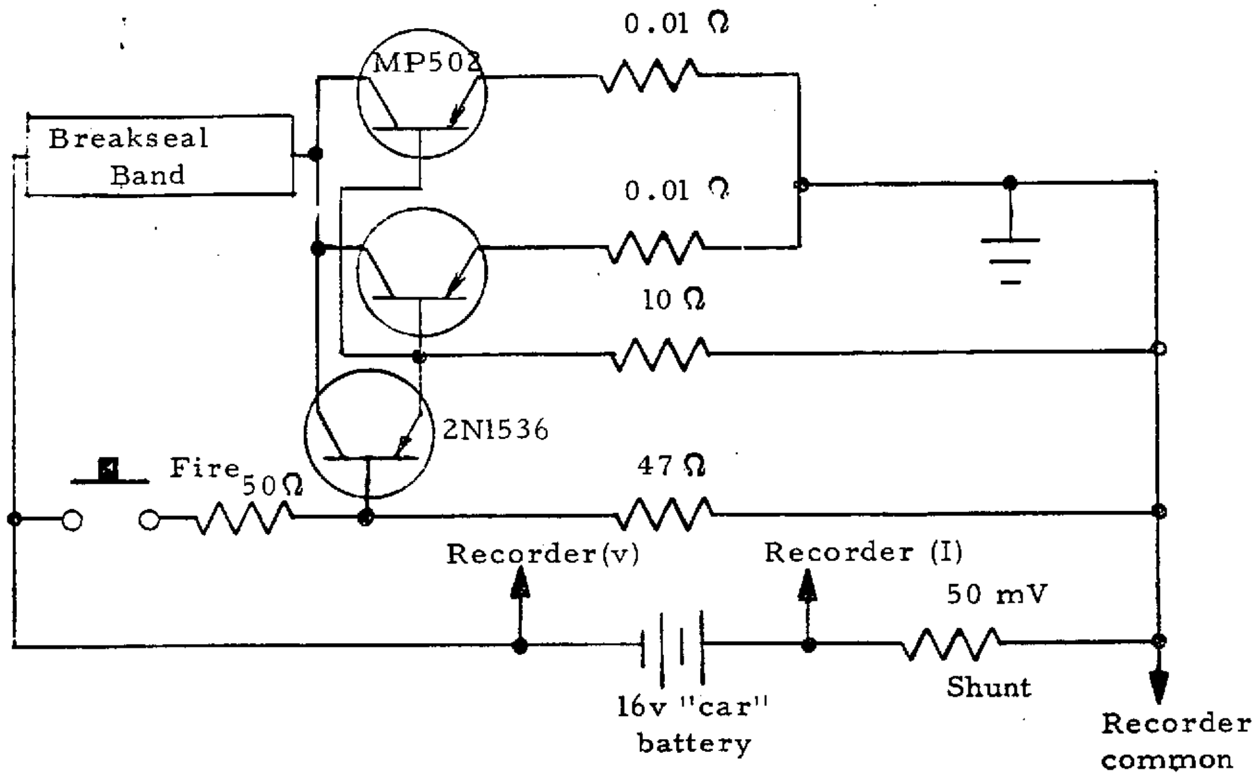


Figure 2 - Breakseal Firing Circuit

Special sensing equipment had to be designed and constructed to determine the shape of the beam and dissipate the 2000 joule pulse emerging from the gun. A beam scanning system was constructed. This consisted of a 16.67 RPM synchronous motor driving a 1/2 inch diameter Wilson rotary seal. On the inside of the vacuum chamber were mounted two 1/8" diameter tungsten rods on a 12" diameter disk tied to the rotary seal. The rods were located 2 inches and 6 inches from the axis of rotation. (see Fig. 3)

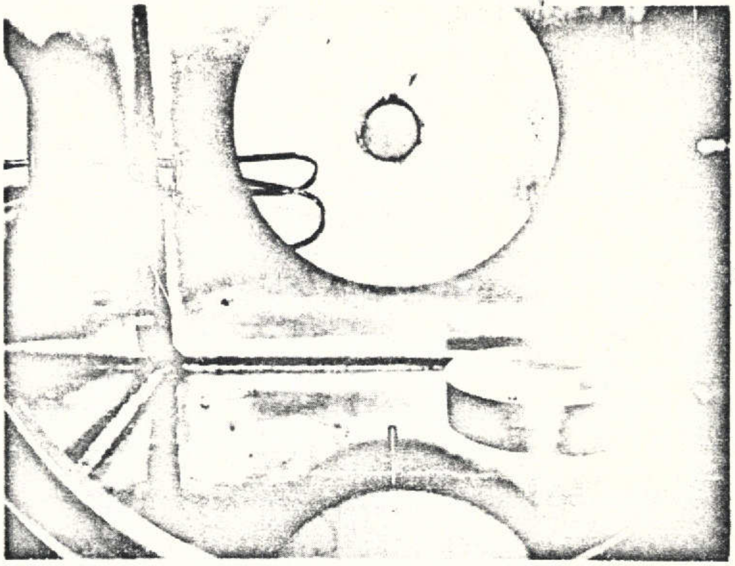


Figure 3 - Beam Scanner

This system allows position sampling of the beam in the vertical plane at distances of 6, 10, 14 and 18 inches from the gun mounting flange. Assuming axial symmetry, the beam shape and size can be determined from this system. Any significant radial accelerations from space charge can also be detected.

Angles of beam divergence are calculated from the readouts by the following method. Given that the scanner is rotating at 16.67 RPM, the velocity of the scanner probe at a radius of 6 inches is:

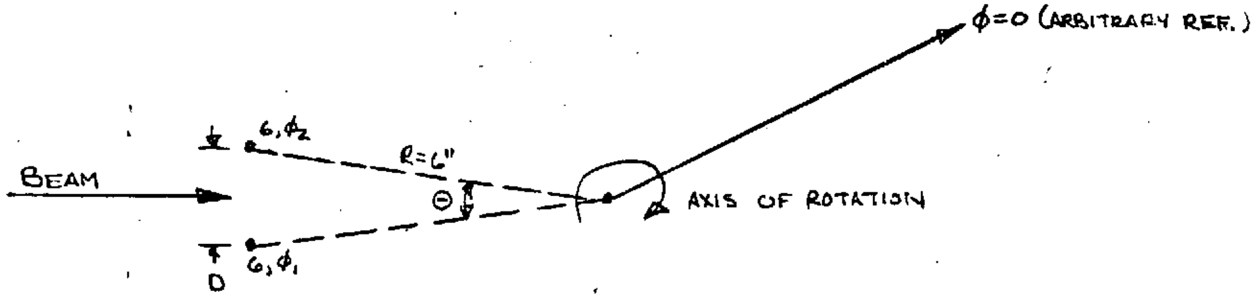
$$V_6 = 16.67 \text{ RPM} \times 1/60 \times 2\pi \times 6 = 3.33\pi \cong 10.5 \text{ in/sec}$$

which is also 100° /sec

For small angles, ($< 10^{\circ}$) the size of the beam is simply:

D = 10.5t, where t is the measured quantity (on chart recorder) assuming the beam lies on a line between the center of the gun and the axis of scanner rotation. For larger angles, i. e. > 10 , corrections must be made for the circular travel of the scanning probe.

Looking at Figure 4,



$$\phi = 100t > 0 \leq t \leq 3.6$$

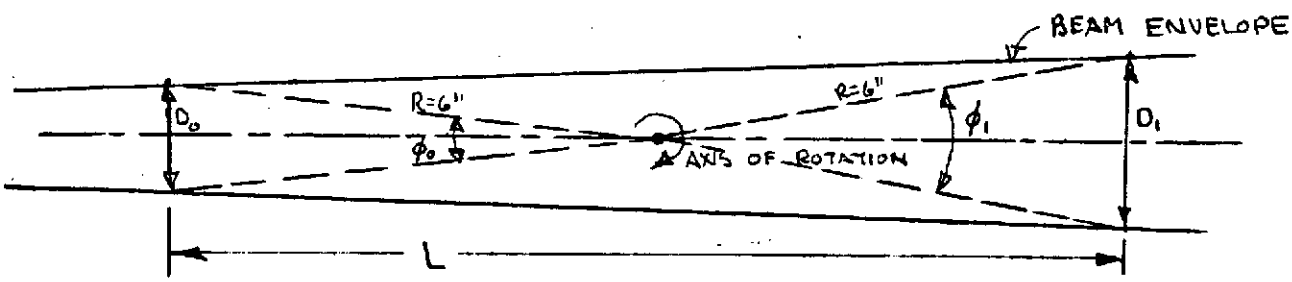
$$D = 2.6 \sin \left(\frac{\phi_2 - \phi_1}{2}\right) = 12 \sin \theta/2 = 12 \sin (50t_2 - t_1)$$

let $t_0 = t_2 - t_1$

$$D = 12 \sin 50\, t_0$$

Again, assuming the beam lies on the line through the axis of rotation, and that it is expanding uniformly (no space charge) we can take the measurements at two points and determine the exact angle of divergence.

Going to Figure 5.



ψ (angle of beam divergence) is :

$$\psi = \frac{57.3}{L} [D_1 - D_0]$$

now $D_0 = 12 \sin 50 t_0$

$$D_1 = 12 \sin 50t_1$$

$$L = 6 \cos 50\, t_0 + 6 \cos 50 t_1$$

then

$$\psi = 57.3 \; \frac{2 \sin 50t_1 - 2 \sin 50\, t_0}{\cos 50\, t_0 + \cos 50t_1}$$

$$\psi = 114.6 \; \frac{\sin 50t_1 \; - 2 \sin 50\, t_0}{\cos 50t_0 + \cos 50\, t_1}$$

$$\psi = 114.6 \tan 1/2 \left[50t_1 - 50t_2 \right]$$

$$\psi = 114.6 \tan \left[25t_1 - 25\, t_2 \right]$$

If we assume a uniform divergence of the beam,

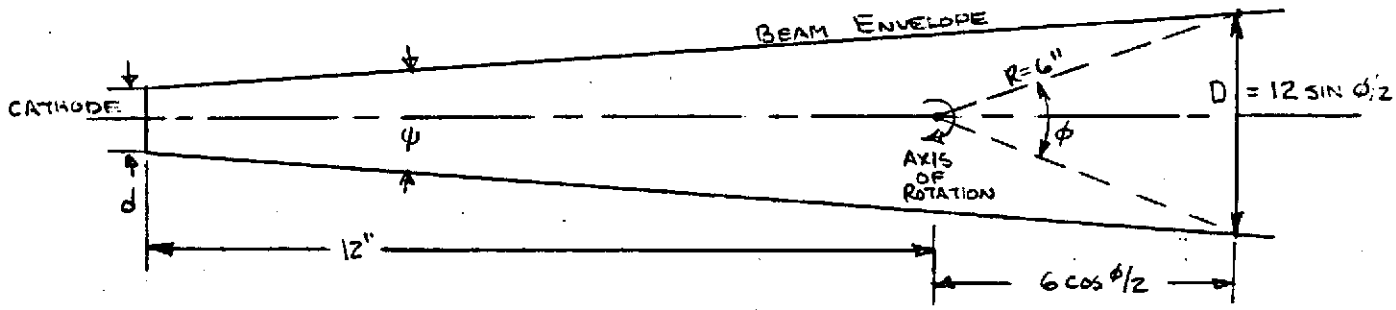


Figure 6

$$\psi = 57.3 \; \frac{D - d}{12 + 6 \cos \phi/2} \;=\; 57.3 \; \frac{12 \text{ in } \phi/2 - d}{12 + 6 \cos \phi/2}$$

again $\phi \; = \; 100\, t$

$$\psi = 57.3 \; \frac{12 \sin 50t \; - d}{12 + 6 \cos 50t}$$

or $$\psi = 9.55 \; \frac{12 \sin 50t - d}{2 + \cos 50t}$$

A simple solution would be

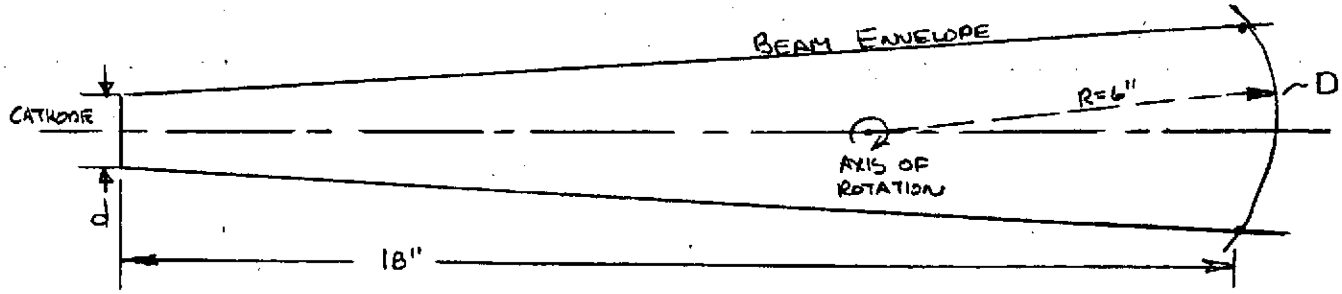


Figure 7

$$\psi = 57.3\ \frac{D - d}{18} = 57.3\ \frac{10.5t - .4}{18} = 57.3\ (.584t - .022) = 33.4t - 1.27$$

It can be shown that the simple solution is adequate in this case up to $\psi = 15$ with less than 10% error.

For situations where the axis of the beam is located significantly away from the center of scanner rotation, complex corrections are required. See Figure 8.

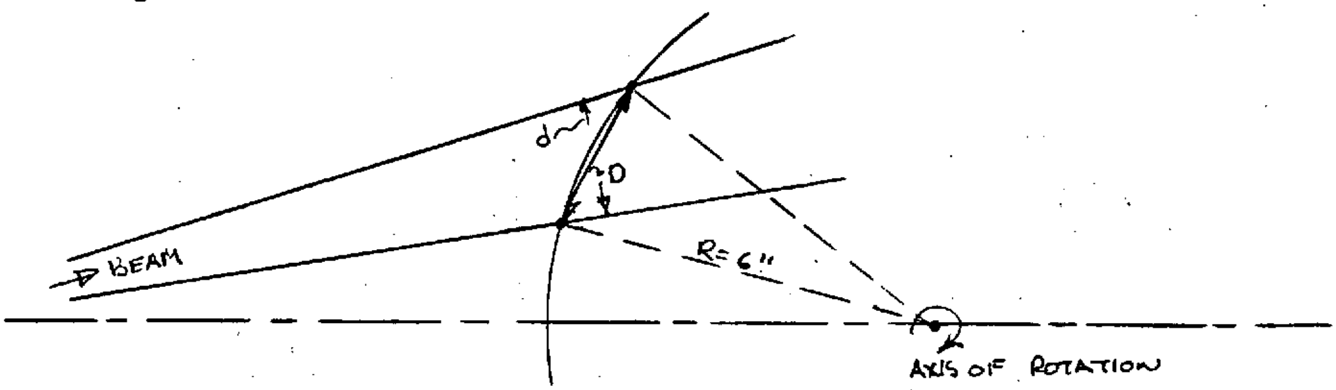


Figure 8

As can be seen, the scanner will give a size, D which is greater than the desired number d. Corrections of this nature were not expected to be required and indeed did not occur in the experimental data.

The beam target consisted of a 12" square stainless steel plate with water cooling. The plate was biased at + 22.5 volts for purposes of secondary-electron suppression so the target could be utilized to measure pulse shape and amplitude for beams of less than 28° full cone angle. Of specific interest was the shape of the leading edge of the pulse where certain discontinuities were found to occur with the older EE 65 gun.

Results

Before presenting the results of this investigation, it is useful to list the specifications of the electron gun as supplied by the manufacturer.

Specifications - EE 65-1

Breakseal

V	15 ± 1 V RMS
I	60 Amps Max inrush
t	3 ± 1/2 sec to break in air

General

Filament voltage	7.5v RMS
Filament current	1.5A RMS
Grid #1 bias for cutoff	-15 VDC max
Anode #1 bias	+ 800 VDC nominal
Anode #2 bias	+ 20,000 VDC
Beam current	100 mA min.
Beam size	10° half-cone max
Lifetime	10 min @ 33% duty cycle in open mode

Table C

Preliminary inspection:

During the first phase of experimentation, some basic problems were discovered with the inspection test plan. The initial form of the plan called for the inspector to perform certain grid characteristic tests by manually sweeping the grid one bias. This particular method would allow large amounts of energy input to the end cap of the sealed gun.

Even though the gun cap was properly heat-sinked for large energy pulses, the vacuum pinch-off was not. This problem resulted in a vacuum failure of the serial #1 gun during first inspection at IPC. A complete failure analysis report is contained in Appendix B. This failure brought about a change in the inspection plan to incorporate automatic grid bias sweeping of a maximum duration of 10 msec with fail-safe protection occurring at 15 msec. A schematic of the special sweep circuit is shown in Appendix C. This system allows only about 10 joules per sweep being applied to the endcap vs over 1000 joules in the earlier version of the test.

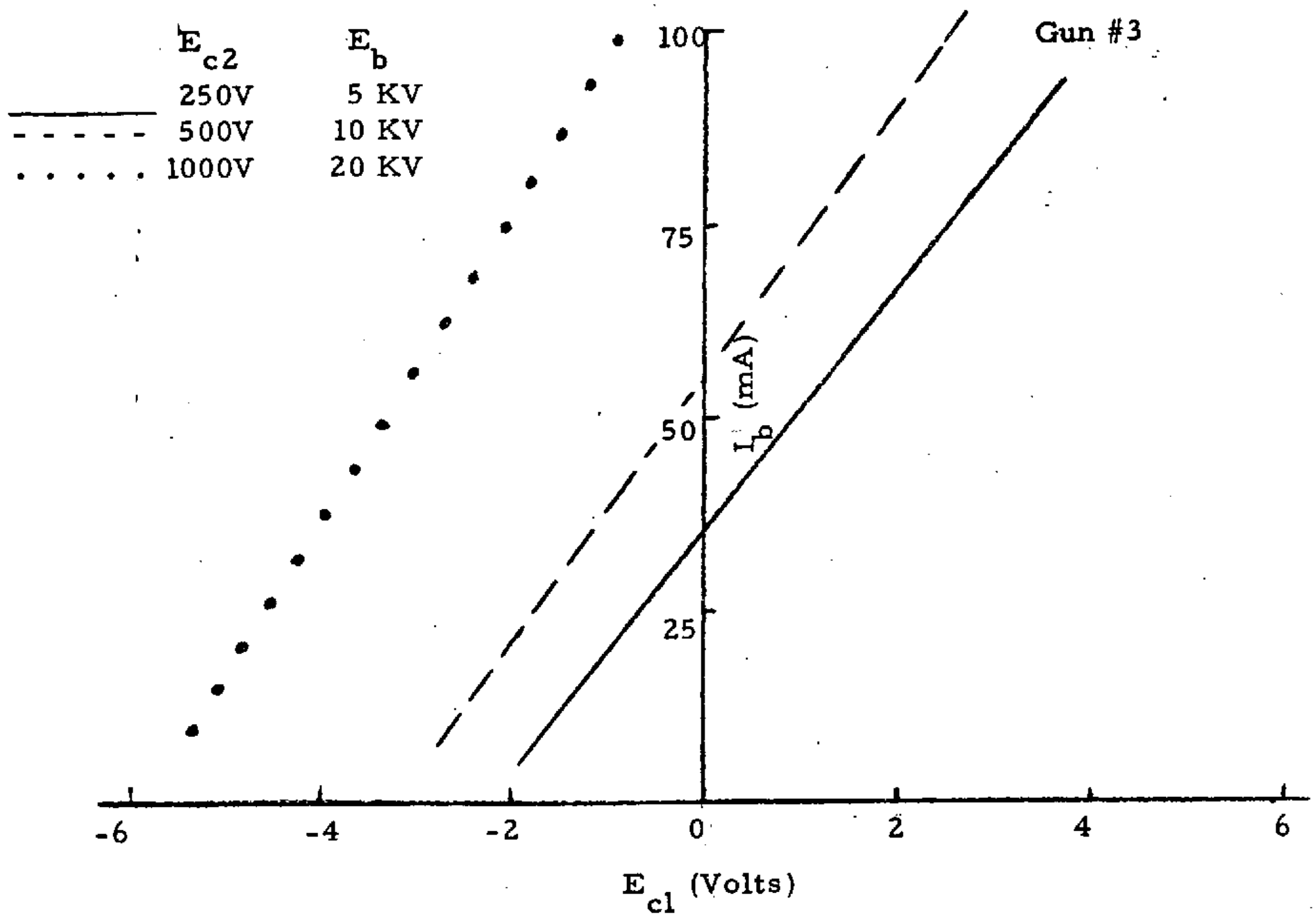
After the failure of the first gun, another prototype was obtained, so we still had two acceptable units for analysis. Pre-vibration inspection was then completed with the results tabulated in Table D.

Table D

Summary of Inspection Data

Gun	Mechanical & Dimensional Check	Filament I @ 7.5 VRMS	Transconductance μ mhos
3	OK	1.55 A	20,000
4	OK	1.50 A	22,500

Gun	Grid Bias (E_b = 20KV, E_{c2}=I_k=100mA)	Leakage I_F = 0, E_b = 30KV, E_{c1}=E_{c2}=0
3	-0.8v	200 μA
4	-1.8v	300 μA



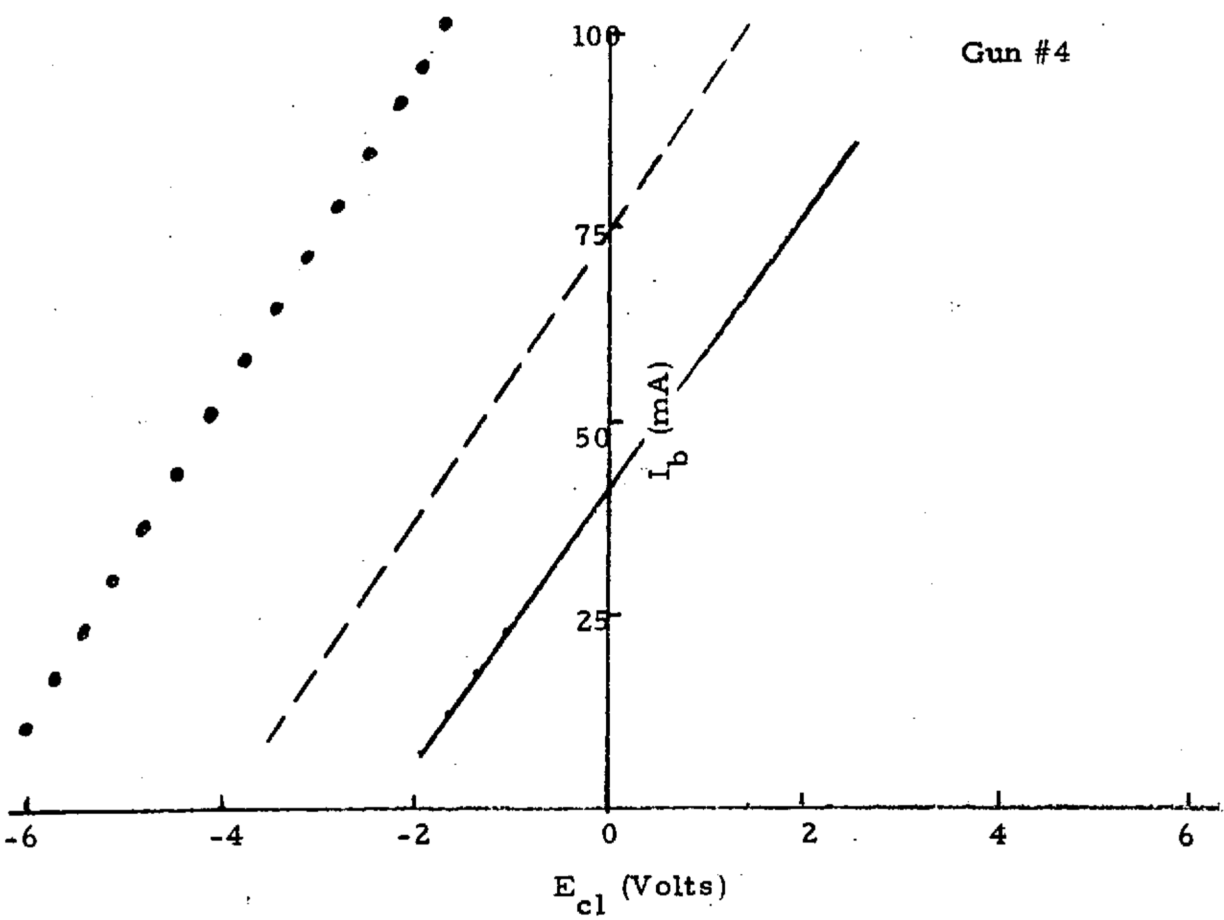


Table D con't. Gun Transfer Characteristics

Shock and Vibration

The shock and vibration tests scheduled in Table A were performed at Associated Testing Laboratories in Burlington, Mass. on Sept. 16 and Oct.13 respectively for gun serial numbers 3 and 4. Serial #3 was tested first and then returned to IPC for reinspection and open-mode analysis. This procedure was intended to insure viability of the first prototype before vibration testing of the second, in case difficulties caused by such testing were not detected by normal inspection procedures.

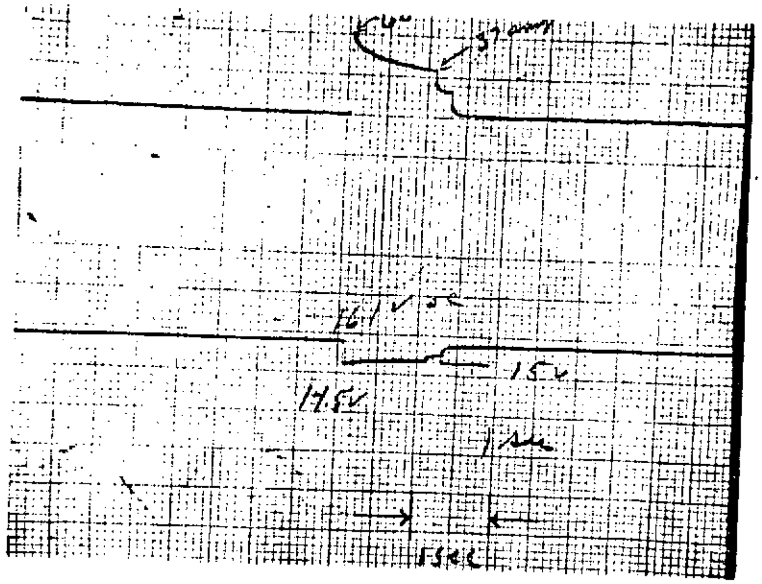
The test reports from shock and vibration analysis are found in Appendix D in total. Post shock and vibration inspection at IPC was completed without difficulty and no significant deviations from the results in Table D were noted in either prototype gun.

Breakseal Testing:

Because the breakseal system was by design, the same as that used on the EE 65 gun, it was determined that only simple proof testing of a number of breakseals would be required. Considerable effort by the quality assurance section insured that not only the design was exactly as before, but that the materials and production processes were identical. Therefore only three breakseals have been activated at IPC (the 2 prototypes plus serial #1 gun), and three at Machlett Labs under the auspices of the government source inspector.

The simple testing at IPC involved firing the breakseal at 15 ± 1 volt to show that it did work and that the time to break would be less than 3.5 seconds (the specified upper limit). The tests at Machlett were to the specification of 3 ± 0.5 seconds.

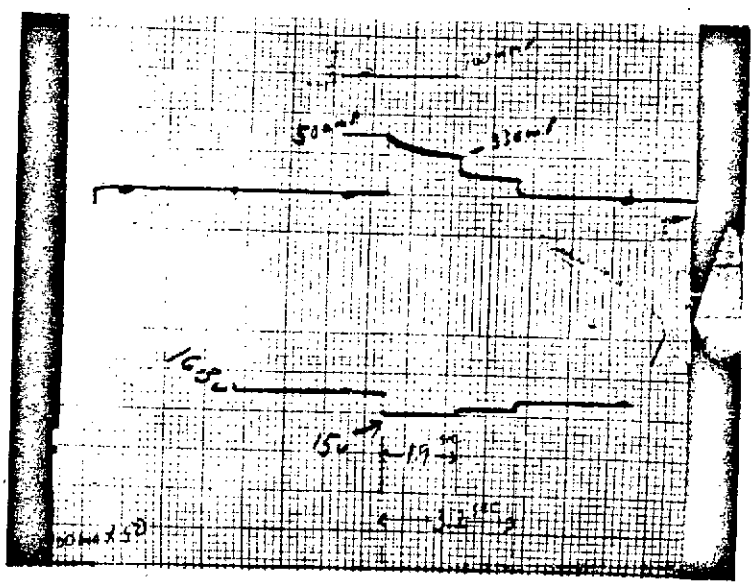
The current and voltage recordings of the three breakseals opened at IPC are shown in Figures 9a, b, & c with the time scale as indicated.



Current

Voltage

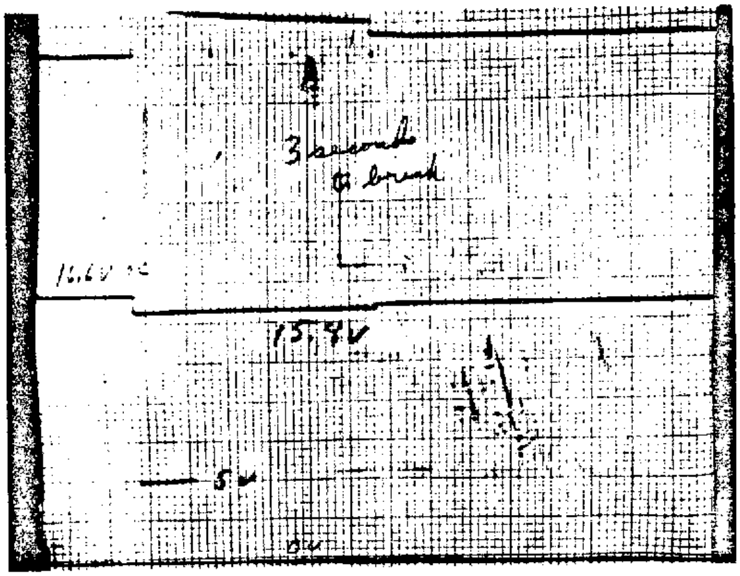
Figure 9a - Gun #1 Breakseal



Current

Voltage

Figure 9b - Gun #3 Breakseal



Current

(47 A peak)

Voltage

Figure 9(c) Gun #4 Breakseal

Three breakseals were opened in air on 12/16/70 at Machlett Laboratories as proof of performance. All three opened within 3 ± 0.5 seconds with 15 v RMS 60 Hz AC applied.

The first two breakseals were opened with a simplified version of the circuit in Figure 2, as shown in Fig. 10. The last gun (serial #4) was opened with the full circuit of Figure 2 as this represented the system to be used on the flight payload, with the exception of the use of lead-acid "car" batteries in place of the not-yet-available silver-zinc flight cells.

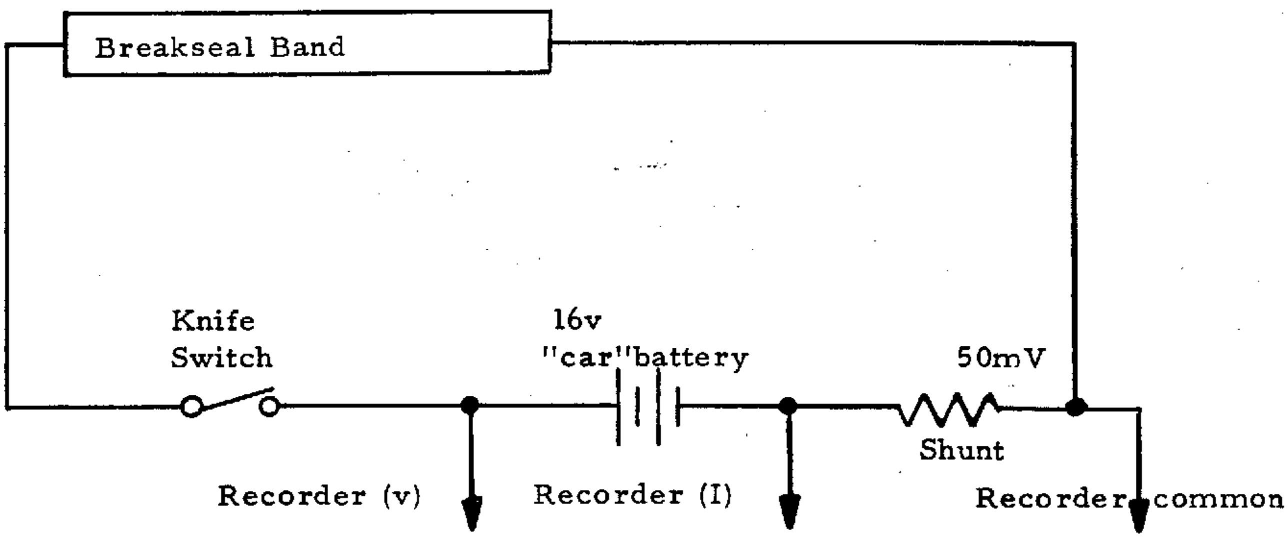


Figure 10 - Simple Breakseal Firing Circuit

Electron Optical Studies:

The tests outlined in Table B were utilized during these experiments and the data compiled in a series of graphs and photographs. The first gun to be tested (in the circuit of Fig. 1) was found to have no emission when first turned on. This was traced to a leak of sulfur hexaflouride gas being used around the gur for insulation, resulting in a poisoning of the cathode. The cathode was reactivated per Machlett Labs' procedure as outlined in Table E.

Table E - Reactivation Procedure for Cathode

I_f = 1.4 amps

I_{c1}(mA)	I_{c2}(mA)	E_{c2}(mA)	Ib(mA)	Eb(volts)	Time(min
30					5
50					5
100					3
40	40	225			5
30	10	250	35	400	5
30	11	325	50	800	10
30	11	350	60	1000	10

The first gun was mounted in a modified EE 65 socket, as the new sockets were not yet available. The second gun (serial 4) however, was mounted in a fixture with demensions identical to the intended flight package to test voltage holding ability. The socket used in the second case is a special design resulting from a cooperation between IPC and Jettron Products, Inc. of Hanover, New Jersey. A picture of the socket, test plate, and gun is shown in Figure 11.

Also included was an insulating coating underneath the gun mounting flange (Martin hardcoat anodizing) as was intended on the flight package for purpos of monitoring the second anode current. The results of this test were inconclusive as short occurred between anode 2 and ground after a few pulses. The short's origin was not traced as after the test plate was removed from the vacuum system no evidence of a short remained.

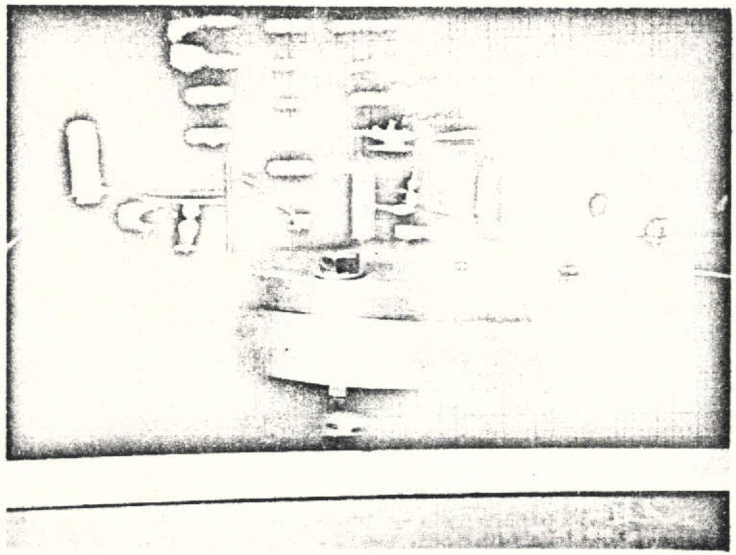


Figure 11 - Gun Test Fixture

A typical data readout from the Visicorder is shown in Figure 12 with the various signals identified. Certain types of data could not be handled by the Visicorder because of their origin being at the cathode potential (in this case the anode is at ground, the cathode at -20Kv) and had to be recorded by hand. Pulse shape data taken from the beam target was done with a Tektronix storage CRT and Photographed.

Reduction of the data taken as shown in Figure 12 was accomplished by measuring the FULL WIDTH AT HALF MAXIMUM (FWHM) in time on the 18" probe and reducing this to a number corresponding to the angle at half maximum by the techniques outlined earlier. The total data was first analyzed to see if indeed the beam did pass through the axis of scanner rotation and that space charge effects were negiligible (i.e. no radial acceleration). As these conditions were found to be true, a simple reduction was allowable. Analysis of the scanner traces also indicated that the base widths of the scanner data were about 2 x FWHM in time. Individual gun results as a function of output current and energy plotted against the first anode bias shown in figures 13 and 14 with composite data displayed in Figure 15.

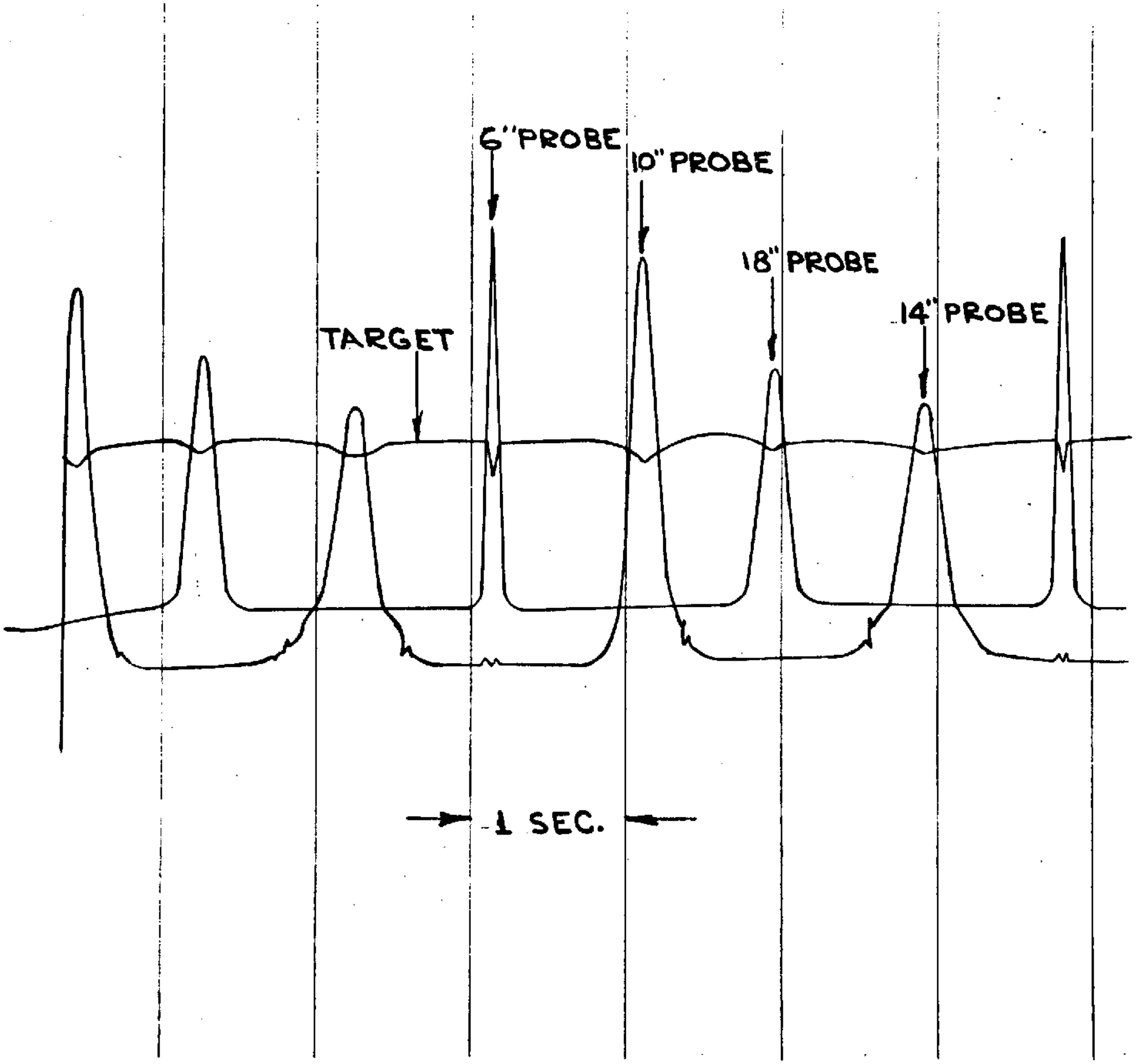


FIGURE 12- TYPICAL BEAM SCANNER DATA

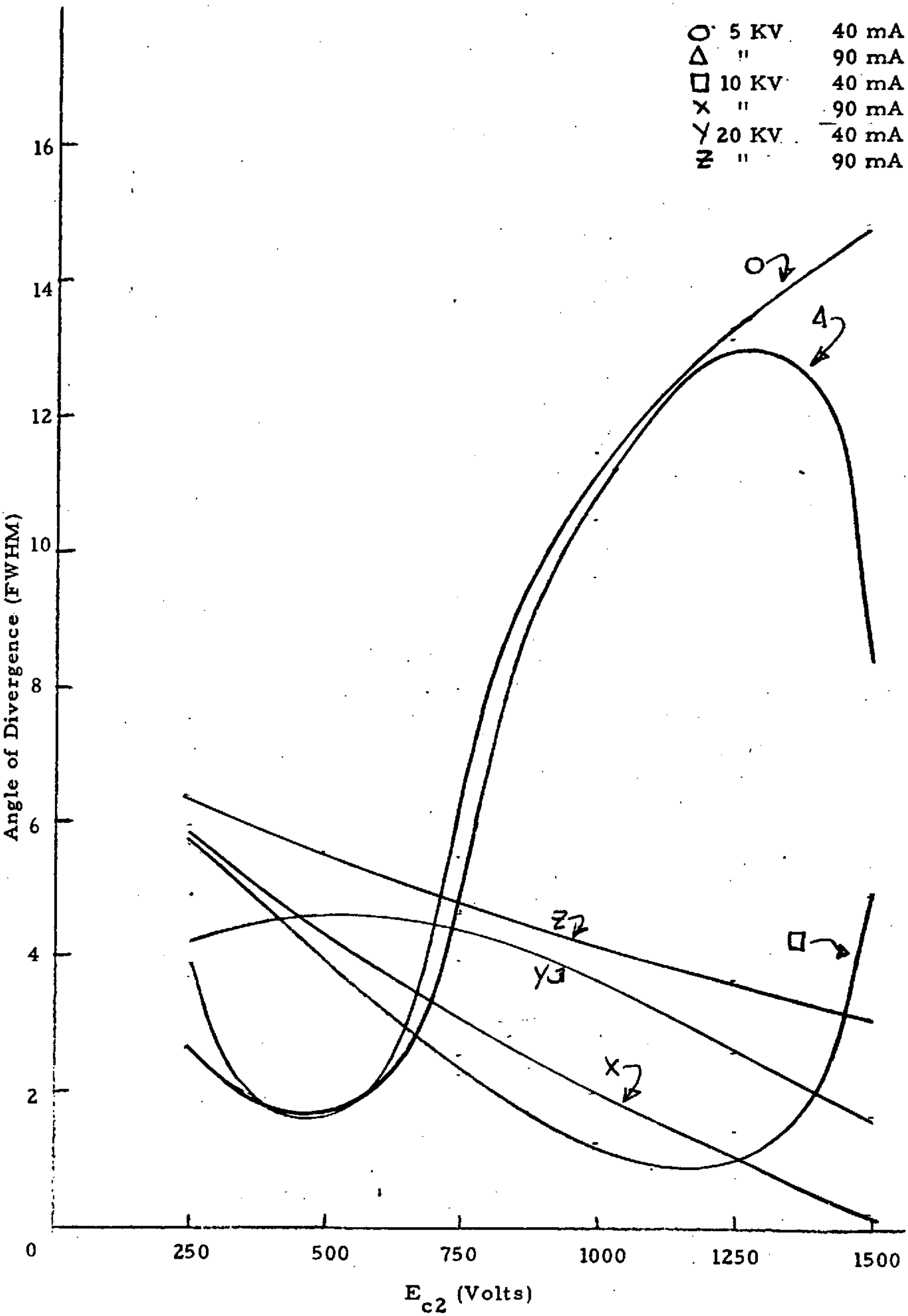


Figure 13 - Gun #3 Optics

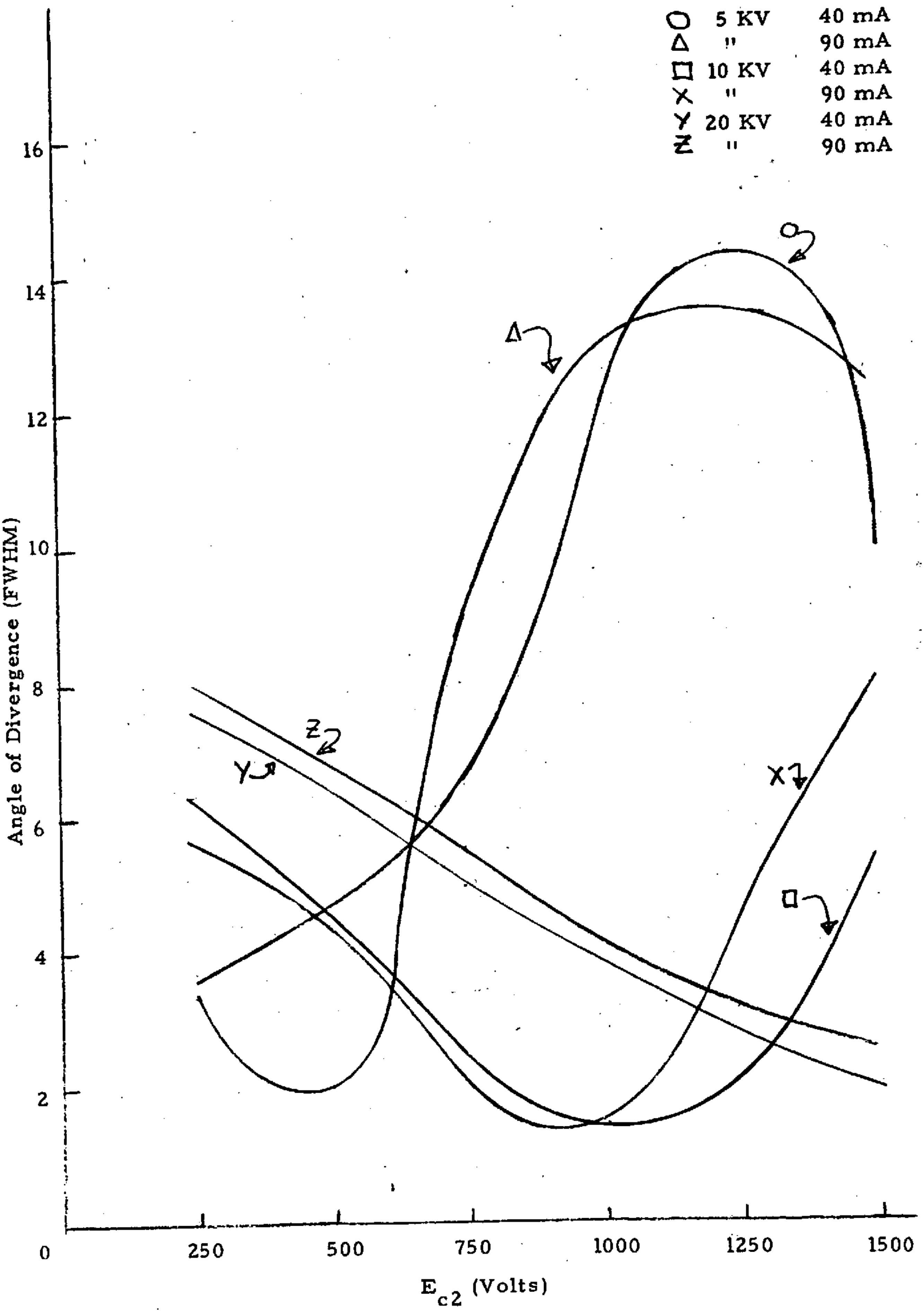


Figure 14 - Gun #4 Optics

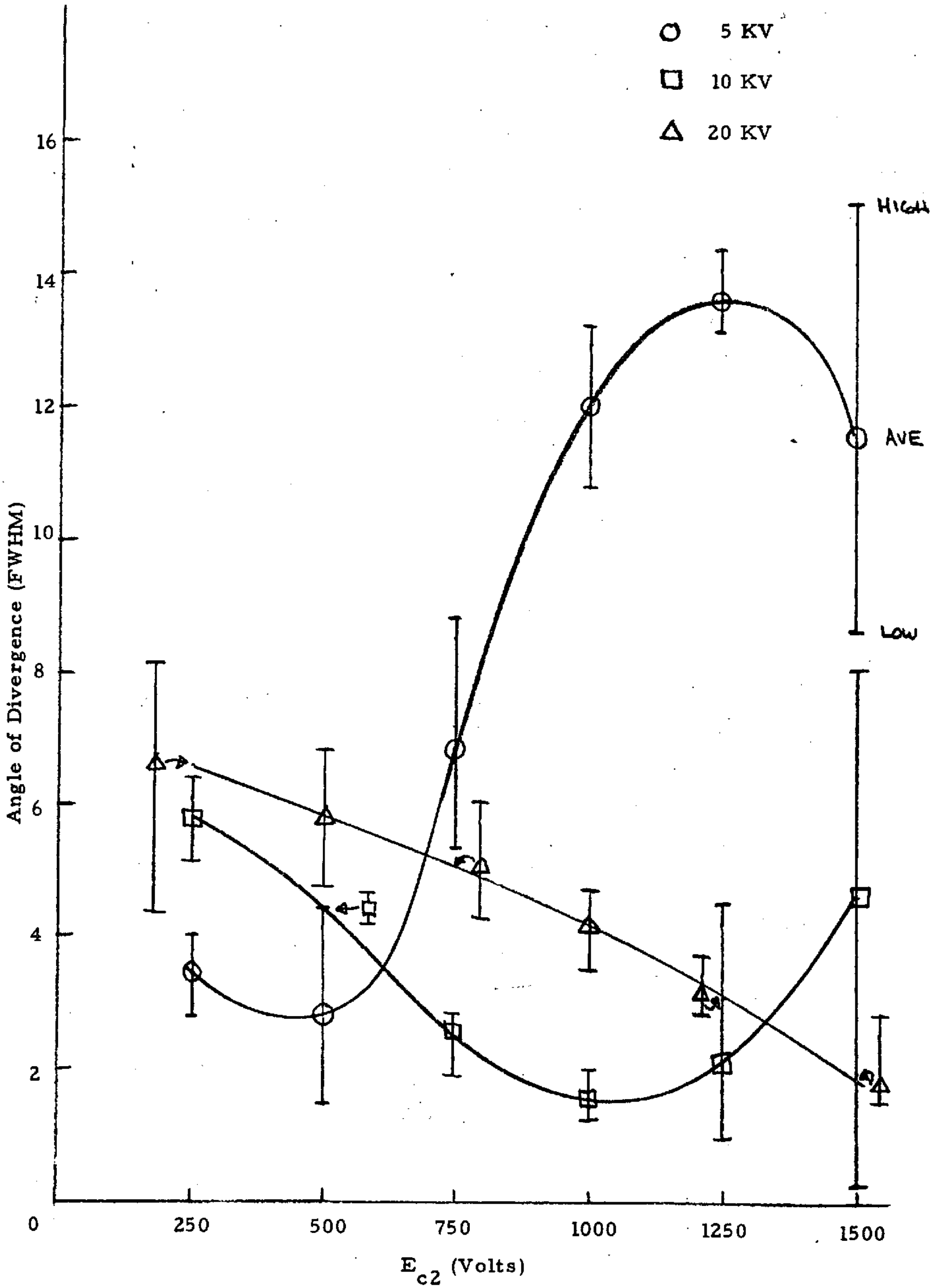
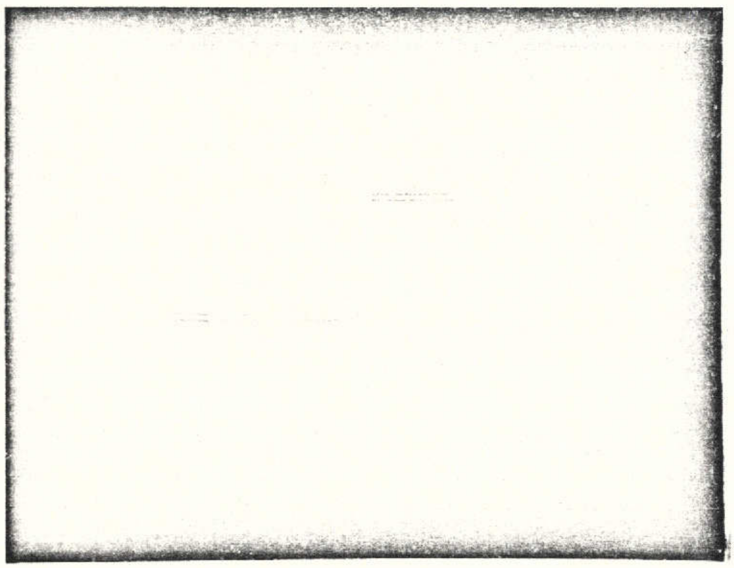


Figure 15 - Average Optics

Data was taken at cathode currents of 40 and 90 mA as these were points corresponding to slightly greater than the intended flight operating currents of 33 and 83 mA.

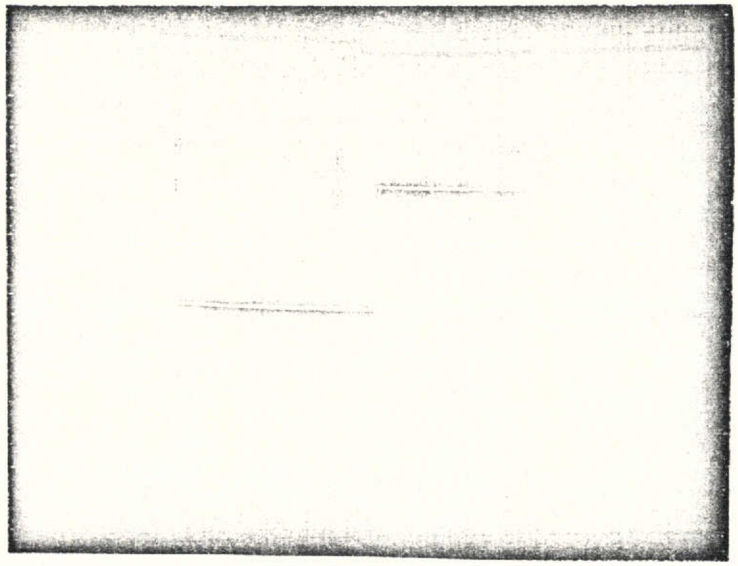
Pulse shape data taken with oscilloscope photographs is shown for representative 1 and 6 second pulse lengths in Figures 16 through 21.



→ .2 sec/cm

↓ 20 mA/cm

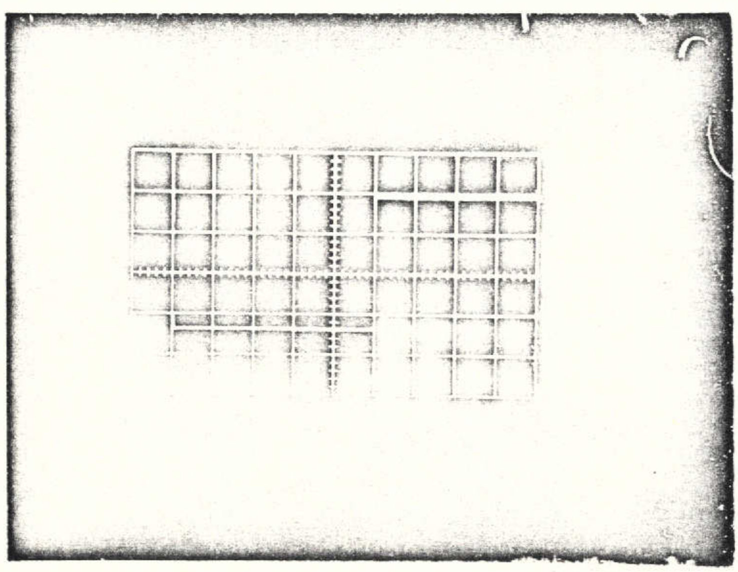
Figure 16 5KV pulse, 1 second



→ .2 sec/cm

↓ 20 mA/cm

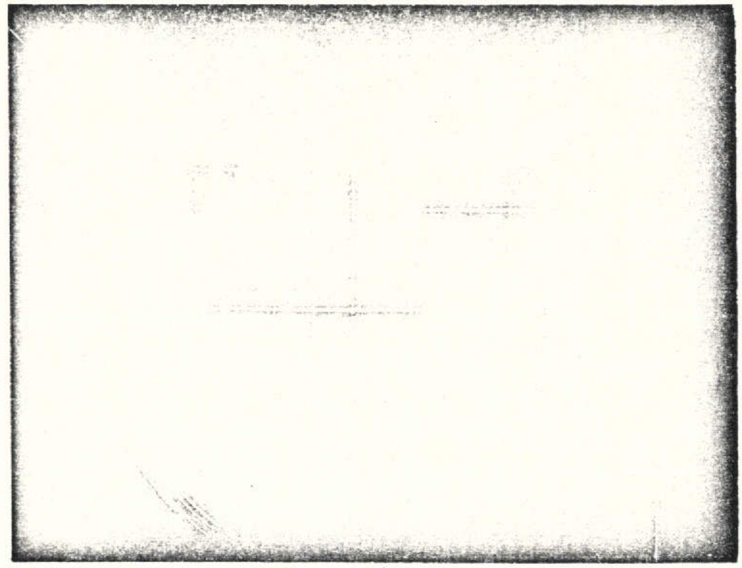
Figure 17 - 10 KV Pulse, 1 second



→ .2 sec/cm

↓ 20 mA/cm

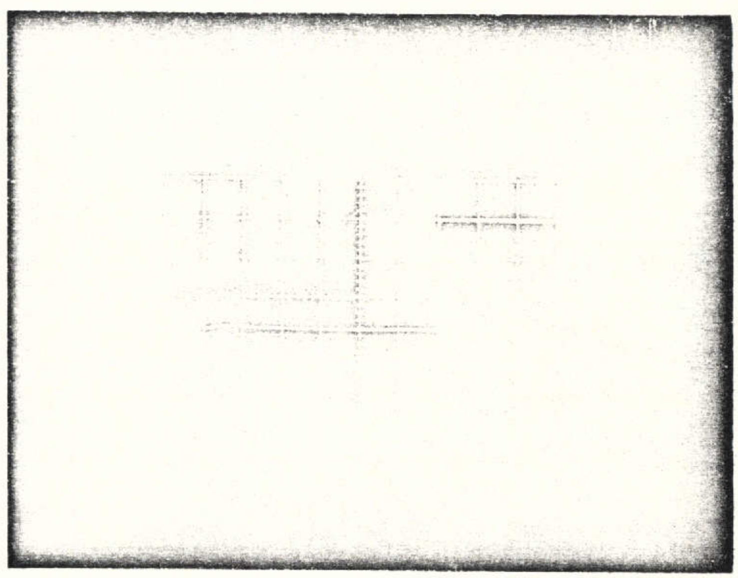
Figure 18 - 20 KV Pulse, 1 second



→ 1 sec/cm

↓ 20 mA/cm

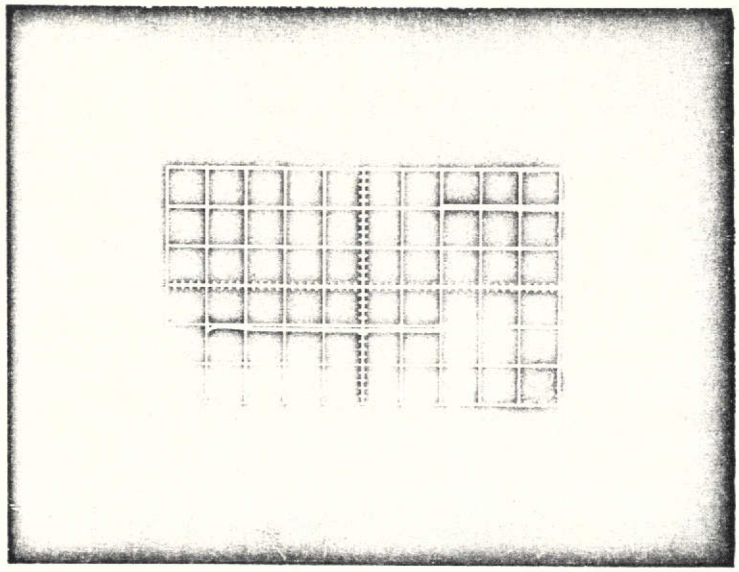
Figure 19 - 5 KV Pulse, 6 seconds



→ 1 sec/cm

↓ 20 mA/cm

Figure 20 - 10 KV Pulse, 6 seconds



→ 1 sec/cm

↓ 20 mA/cm

Figure 21 - 20 KV Pulse, 6 Second

Also of interest was the response during the rise of the pulse and a typical fast trace is shown in Figure 22.

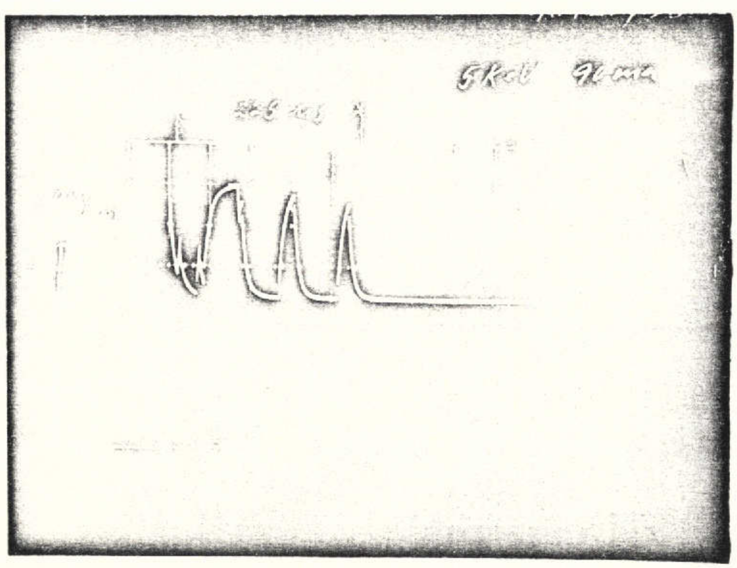


Figure 22 - Pulse Rise Shape

This photo indicates a considerable distrubance on the rise of the pulse, but this was determined to be traceable to contact noise on the relay used to program the gun on and off. Both prototypes displayed the same phenomena.

Calibration of the average target current as recorded on the photographs indicated that only about 75% of the H. V. power supply return current was being received on the target plate. An investigation showed that even though the primary beam was small enough to be completely on the target, about 25% of the return current was on the rest of the vacuum chamber.

An investigation, both theoretical and experimental, indicated that a large amount of secondary electrons with energies greater than 22.5 eV would be produced with primary electrons greater than 5 KeV and also reflected primary electrons at full energy would result. An experiment involving determining the collection efficiency of the target vs bias voltage up to 600 V was conducted with the results shown in Figure 23.

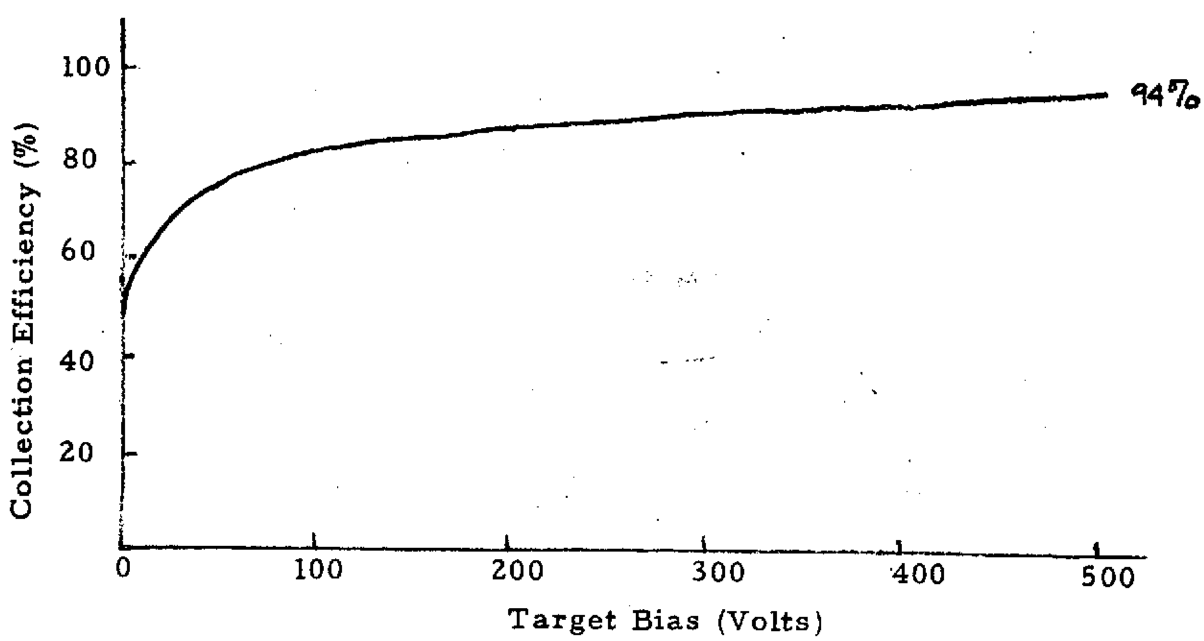


Figure 23 - Target Efficiency

The curve found experimentally agrees with the literature, not only with respect to true secondaries, but also to the expected number of reflected primary electrons as only about 95% c llection efficiency is obtainable at 600 V bias. The number of expected reflected primary electrons is ~5%.

First Anode Characteristics

Since during the original inspection of the first gun (serial #1) it was discovered that the first anode behaved like a negative impedance under certain operating conditions, special care was taken during the open gun tests to determine the actual operating characteristics of the first anode. The resulting data is shown in Figure 24.

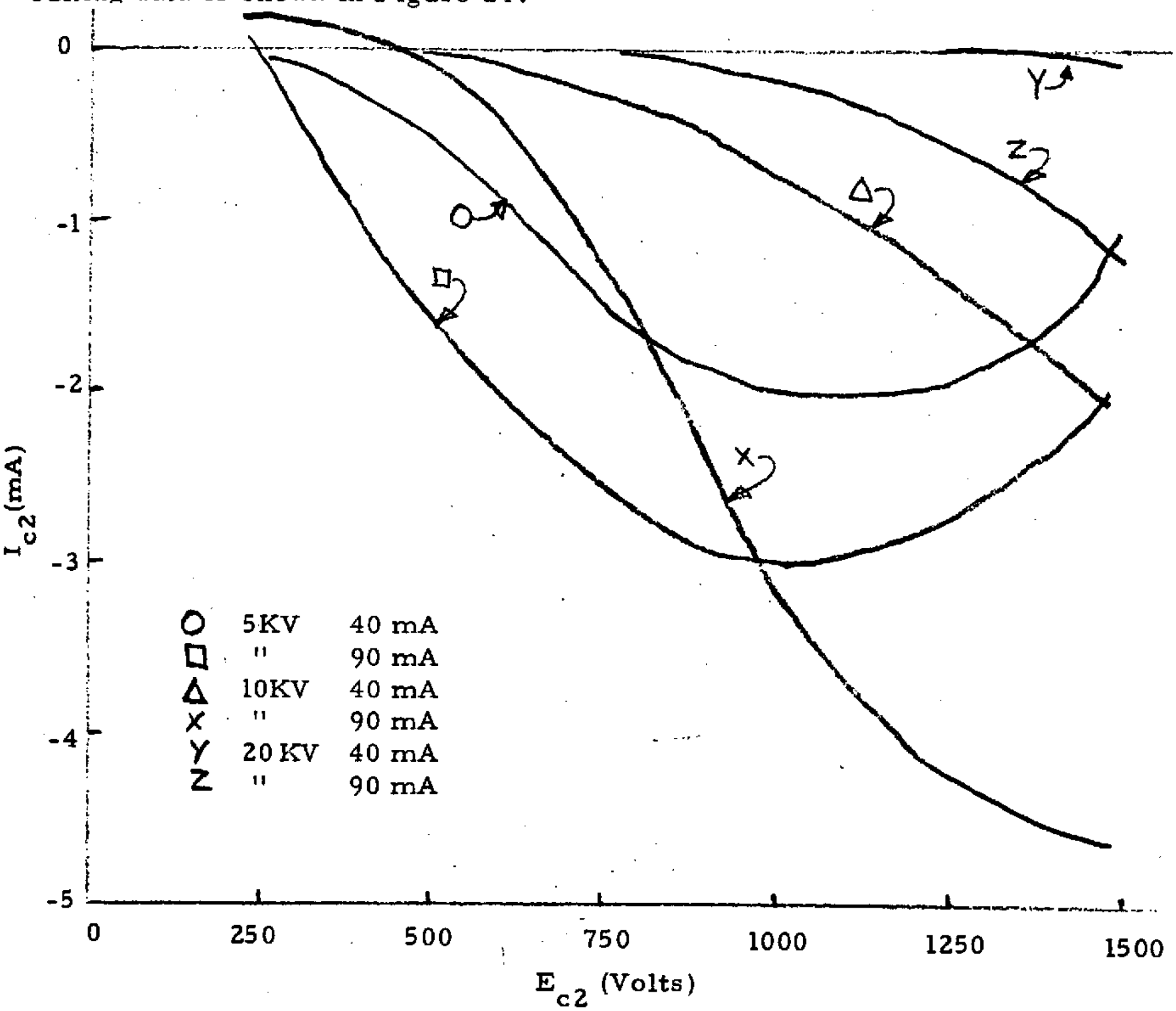
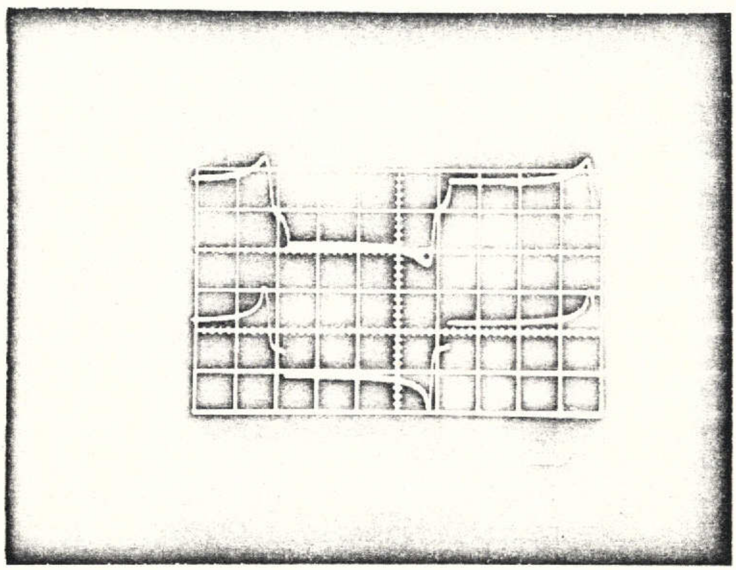


Figure 24 - First Anode Characteristics

Although we did not get good data on the second anode current, it was noted that it was normally less than lmA except when the first anode was highly into the negative current region, where the second anode would increase to the order of 10 mA.

Other experiments:

It was necessary to determine the feasibility of operating the heater from a 10 KHz square wave. Since the heater was constructed from a helix, it was thought that the inductance might be too high. Time constant measurements with a GR impedance bridge, however, indicated that one might expect the order of 2 μsec time constant when the heater was warm ($R \sim 5\Omega$, $L \sim 10\,\mu H$). The heater was tested with a waveshape similar to the expected waveform to be used on the flight package. The resulting current waveshape is shown in Figure 25.



↑ 10 v/cm

→ 10 μsec/cm

↑ 2.5 A/cm

Figure 25 - 10 KHz Heater Drive

Lifetime studies:

Both prototype guns were tested for lifetime capabilities, the tests were performed at an accelerator voltage of 20 KV and a cathode current of approximately 90 mA. The guns were pulsed at 50% duty cycle with about a 5 second pulse length.

After a period of about 30 minutes, the guns would begin to decay in output amplitude down to almost no output after one hour. During this time the base vacuum pressure was noted to rise from 1×10^{-6} torr to as high as 5×10^{-6} torr. Both guns displayed the ability to recover their output after a period of pumping with the filament on at reduced power. (Usually overnight.)

Conclusions:

A number of areas of concern are evident in the foregoing results. The first of these is the apparent weakness of the vacuum pinch-off with respect to power density, as compared to the rest of the endcap. Since the normal routine of operation calls for the electron guns to be checked out on the payload by a "ground-check program", one must be concerned with the maximum energy that can be imparted to the endcap under any condition, including system fault, in the closed mode.

Based on analysis of the most probable areas of failure, it is deduced that up to a 6 second pulse at full power might occur (corresponding to 10 KJ on the endcap). Discussions with the manufacturer point out that the end-cap will reach 250° C with only 0.25 watt average power and that temperatures greater than 600°C are serious. It is useful to indicate that these discussions are relevant to operation of the endcap in vacuum as would exist when the payload nosecone is in place, with little or no conductive heat sinking available. Obviously extreme care is necessary to prevent such a fault from occuring. Assuming that the system programming can be accomplished with satisfactory protection, then the only concern will be the reliability of the pinch-off to handle low average power (the order of 1 watt total on the endcap assembly).

There are two simple solutions to the problem which involve minor changes in the endcap design. Figure 26a shows the existing design and Figures 26b and 26c show possible alterations.

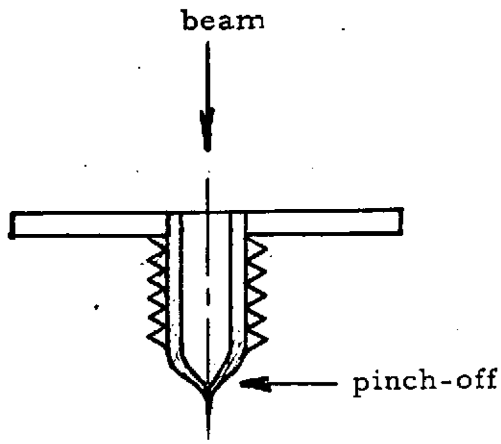


Figure 26a - Existing Endcap Design

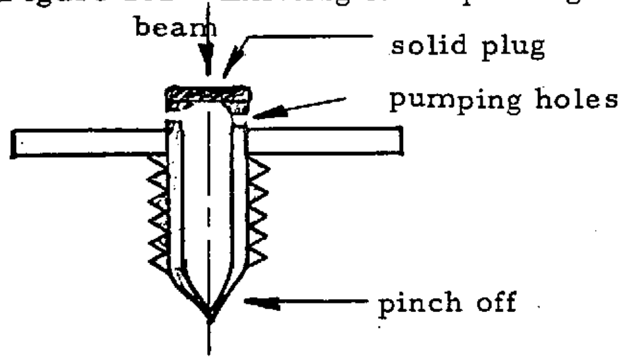


Figure 26b - Alternate Design A

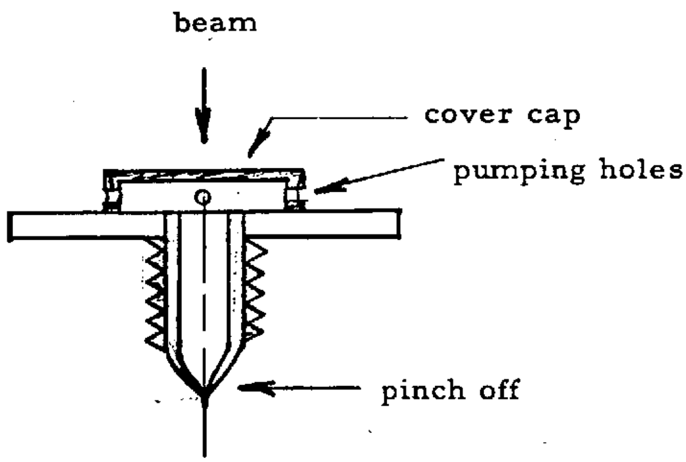


Figure 26c - Alternate Design B

Since changes in design at this particular point in time will possibly cause delays in future deliveries as well as cost increases, an effort to determine the necessity of any change is in order.

A possible method of arriving at a decision on this situation would be to determine the uniformity of construction of the pinch-off from gun to gun as compared to the failed unit by X-ray analysis. If it can be shown that other units have greater material thicknesses in the critical area, then a change in construction is probably not necessary. However, if a good degree of uniformity exists between units, then a recommendation to change the design will certainly be necessary to insure reliability.

In order to insure that a "no change" decision is correct, however, an investigation involving accurate measurements of thermal stress levels on all areas of the endcap assembly will be necessary. Such work would be beyond the scope of the present investigation.

The second area of importance is the electron-optical characteristics of the gun. There are two distinct modes of gun operation suggested by Figure 15. The first is a constant bias on the first anode and the second is a constant ratio between the first anode bias and the second anode bias. Figure 27 shows how these modes affect the electron-optics of the gun. It can be seen easily that the constant ratio mode yields almost a constant output beam angle. A decision as to which mode of operation best fits the needs of the experimenter must be wieghed against the methods of bias in which the first anode behaves in general like a negative impedance.

Before attempting to analyze the operational use of the gun as a "black box" device (in terms of the optics of the output beam), it is useful to hypothesize about the reasons behind the negative behavior of the first anode, thus the third and perhaps most important, area of concern arises.

The most probable cause for electron emission at the first anode is secondary emission. Since most metals have peak secondary-electron emission coefficients which are not much greater than unity, it is suspected that high

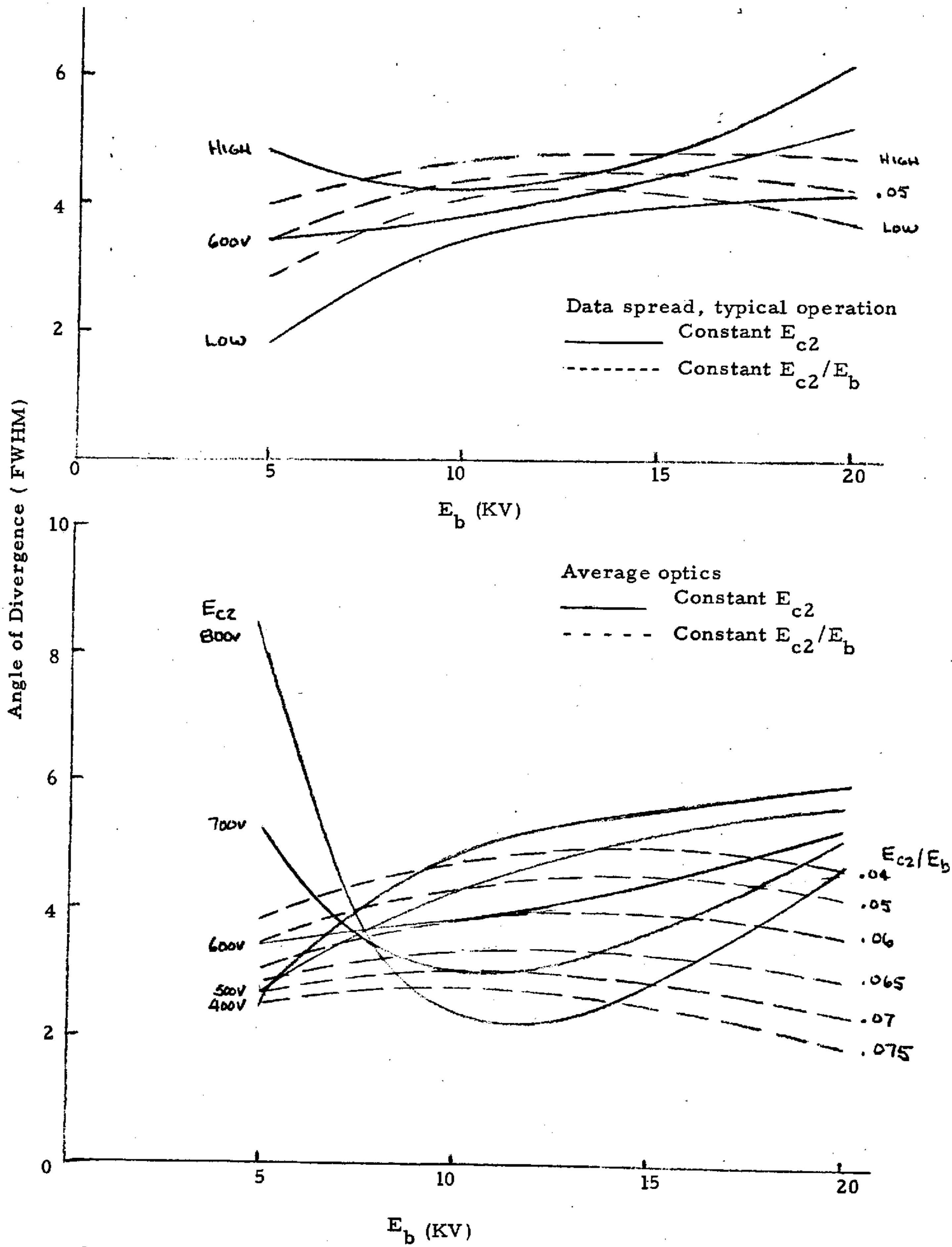


Figure 27 - Angle of Divergence vs Operating Mode

secondary emission yields would have to be derived from some oxide being present on the surface. This is not necessarily true, however if one takes into account the flancing incidence of the primary beam. (see Figure 28). Bruining* shows that as the angle of incidence goes from 0° (at normal incidence) to 90°, the emission coefficient increases exponentially. Therefore values much greater than unity can be easily achieved without the presence of oxides of things like rarium or strontium (from the cathode). The presence of barium alone (not in oxide form) would be insufficient to yield coefficients greater than unity ($\sim$ .83 max).

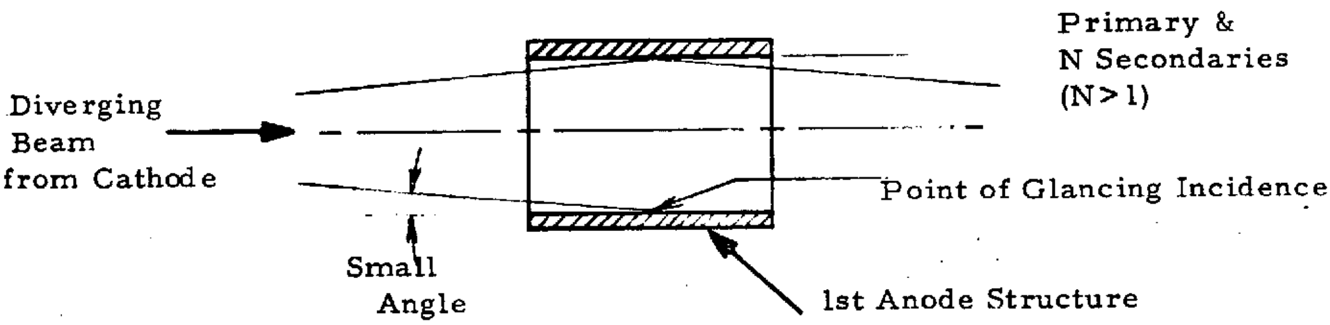


Figure 28 - Secondary Emission at Anode 1

Observation of the surface of the first anode with a micorscope yielded information about the surface as to whether or not the presence of a rough surface would nullify the high yield gained from lancing incidence. Although severe tool marks were found, most of the surface was relatively smooth, thus substantiating the probability that metal alone could be responsible for the observed results.

Since an intuitive dislike of having to operate with a negative impedance generates the need to further analyze and correct the causes of same, more studies should be performed to prove or disprove the foregoing hypothesis.

* Secondary Electron Emission, Bruining, H.McGraw Hill-1959 pp 100-109

Lack of time, again, does not permit this. Therefore, provided that the negative impedance can be handled satisfactorily, the use of the gun as a "black box" with certain inputs to obtain the required output is in order.

This leads to the final aspect of the third problem - how to supply the first anode bias. There are three distinct possibilities:

1. Separate Converter
2. Tapped High Voltage Bleeder
3. Zener Stabilized H. V. Bleeder

The use of a converter puts complications on the flight package design because of increased parts count, but provides the flexability of being programmable, thus allowing either mode of operation (fixed voltage or fixed ratio). The tapped high voltage bleeder is the simplest approach, but allows a problem to develop- that of runaway on the first anode. This is true since the negative impedance will cause the anode bias to increase as the current increases, which in turn causes a further increase in the bias and so on. This is evident from the curves in Figure 24. The advantage of the tapped bleeder is fixed ratio operation, at the sacrifice of the heavy bleeder current necessary to stabilize the runaway condition. The third approach satisfies the condition of simplicity and fully stabilizes the first anode bias at the sacrifice of being restricted to fixed voltage operation. Figure 29a shows how the zener/stabilized bleeder would be implemented Figure 29b shows an alternate appreach to the method in Figure 29a which allows some degree of programability with minimum parts increase.

Obviously the choice of fixed voltage or fixed ratio operation is quite interrelated between the demands of the experiment and the method of obtaining the first anode bias. The fixed voltage method may be the simplest to provide stabilization on the first anode whereas the tapped bleeder would be more reliable, due to possible zener diode failure from high voltage surges. Assuming that adequate protection of zeners can be implemented, then the zener-bleeder combination is favored due to its ability to hold stable voltages under the negative impedance condition. If fixed ratio (constant angle) is determined to be important, then the circuit of figure 29b may be used.

A further area of concern is lifetime and cathode poisoning. Guns

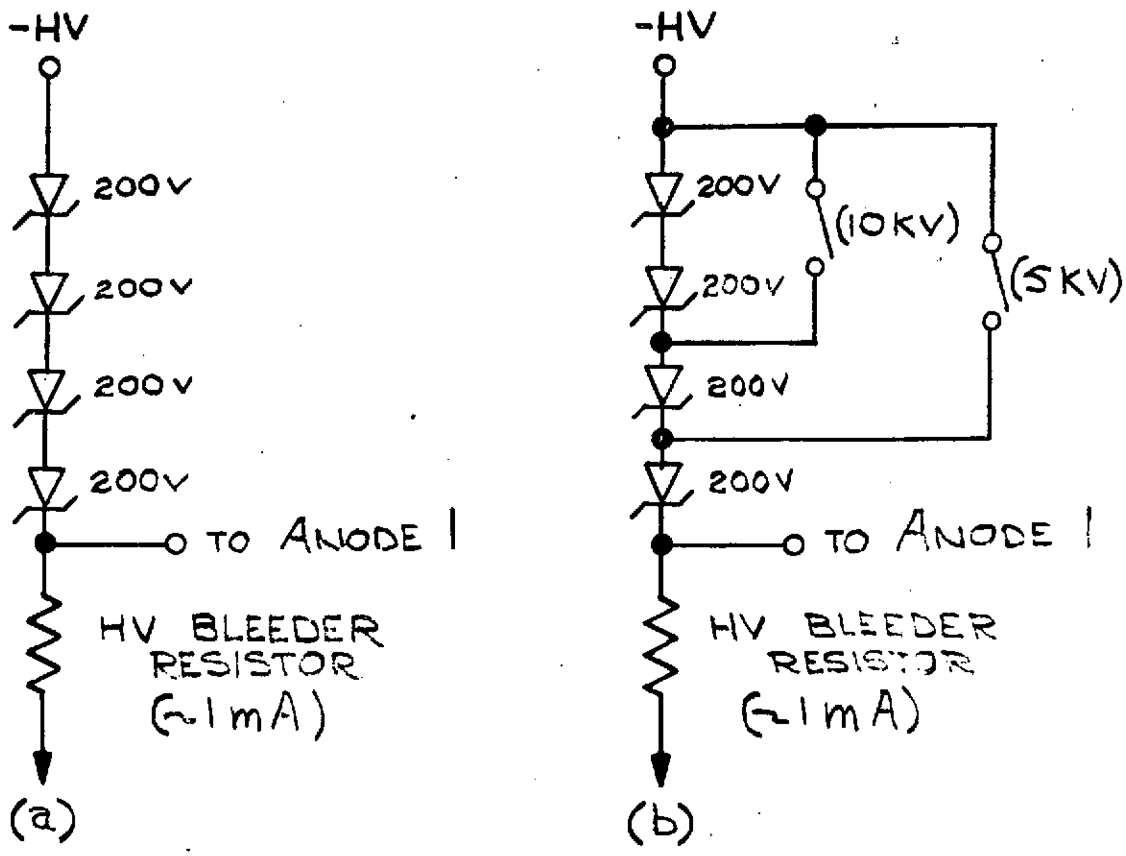


Figure 29 - Methods of Anode One Biasing

of this type are intended to be operated in a "clean" vacuum. However, once they are opened to their operating environment, a "clean" vacuum is usually not available because of outgassing and attitude control systems. This means that the cathode must be resistant to poisoning over the length of the mission. Controlled tests were not performed during the experiments outlined in this report to determine the exact characterisitics of the cathode being presently used. Appendix E contains a published report by the Machlett Laboratories concerning the phormat cathode being used and indicates greater lifetime expectancy under normal (closed tube) conditions than that achievable on earlier models (ie EE-65).

Further results in favor of adequate lifetime capabilities are: Gun #3 was recovered from poisoning with SF_6 by reactivation. Both guns tested ran for 30 minutes continuous pulsing before deterioration in an unclean vacuum with recoverability.

The mention of an unclean vacuum system is difficult to substantiate with proven fact except that (1) the system pressure was never better than 1 x 10^{-6} torr with LN_2 in a system that should easily reach 10^{-7} torr without LN_2 and (2) the test system originally contained a mercury pump which has proven back streaming difficulties as evidenced by visible Hg in the main chamber. These two points are felt necessary enough to indicate that the test vacuum chamber was not "clean" at all and did provide high level of contaminates including at least some Hg. Other contaminates which may have been present are unknown as to their constituents.

More work in the area of cathodes is clearly necessary from these sketchy results and should be performed in an ultraclean vacuum system (Vac Ion or similar) with possibility of full bakeout considered. This would allow control of poisonability tests without being affected by unknown system contaminates.

It is concluded however, that although the experimental program is obviously lacking in detail concerning certain areas, that the gun will be satisfactory for flight use with some future changes in design being probably necessary for continued reliable use.

APPENDIX A

Serial Number__________

Specification I/ML-EE65-1
Revision 3
Date 10/21/70

Quality Assurance Provision
for
Acceptance Testing
of
Electron Guns, Electron Accelerator Package

Contract NAS 9-10399
IPC WA - 89107

Prepared by W. E. Starks
Approved R. V. James
R. V. James

ION PHYSICS CORPORATION IPC
A Subsidiary of High Voltage Engineering Corporation
BURLINGTON, MASSACHUSETTS

1.0 Scope

This procedure defines the acceptance tests to be performed on the Electron Guns, Electron Accelerator Package, in order to verify the operating condition and quality of performance

2 0 Applicable Documents

The following documents are applicable to the equipment for which the tests described in this procedure are intended:

IPC Drawing Numbers

C - 1055-002 (sheets one and two)

3.0 Test Requirements

3.1 General

These units will provide a 100 milliampere electron beam at a maximum energy of 20 KeV operating at a 33% duty cycle in output power for a minimum lifetime of 10 minutes. The ensuing tests will not involve testing units to these limits as destructive testing would be necessary to achieve this information.

3.2 Test Equipment

The following test equipment is required for the tests described in this procedure:

(1) Oscilloscope, Tektronix Model 536 with 2 IAI's or IA2's plugin units, or Tektronix Model 502A used X-Y.

(2) Camera, Tektronix Model C-19 or Tektronix Model C-27 with 3000 speed Polaroid Film (black & white).

(3) Power supply, Kepco Model ABC, 0-10 volts, 0-3 amps

(4) Power supply, Sorenson Model QRB 40-.75, 0-40 volts, 0-750 mA

(5) Picoammeter, Keithley Model 414

(6) Simpson Multimeter, Model 260-5M, or RCA model WV98C VTVM

(7) Hartman and Braun Wheatstone Bridge

(8) High voltage power supply, Del Electronics Model 25-200-1, 0-25KV, 0 - 200 mA or Del 25-50-1

(9) Power supply, Kepco Model ABC 0-1500V, 0-10 mA.

(10) 30V Ramp-generator B 1055-042

(11) High voltage power supply, Spellman Model RHR 50PN150, 0 to 60 KV,0 to 5 mA

(12) EE-65-1 Test Fixture

(13) Fan for end cap aircooling

(14) Binocular Microscope or 3X magnifier

This equipment must be maintained on a calibration cycle of once every six months or oftener.

3.3 Test Conditions

3.3.1 Environmental Conditions

Perform all inspection in semi-clean room when possible. In transporting tube to and from clean room, keep in a clean plastic bag and cardboard box to prevent exposure to general plant atmosphere. Handle only with lint free silk gloves or talc-free rubber finger cots.

Tests outlined in sections 6.0 and 7.0 shall be performed with the test unit mounted in item 10 of section 3.2 with the fixture contained in one (1) atmosphere of dry sulphur hexaflouride gas (SF_6).

3.3.2 Power Requirements

The following power sources are required for the tests described in this procedure:

(1) 115 Vac, ±10%, 60 Hz, 0.5 KVA

(2) 208 Vac, 3ϕ, ±10%, 60 Hz, 5 KVA

3.3.3 Test Sequence

All tests must be performed in the order in which they are given in this procedure.

4.0 Visual Inspection

Inspect each unit visually for defects in workmanship and handling. If there is any defect, enter the letter "R" (rejected) in the appropriate space below: if no defect, enter the letter "A" (accepted). In either case, the inspector must sign off the test record. Is the package sealed? (Yes or No) ________ ____

(date) (initial)

TEST DATA

	ITEM	A/R	Date	Initial
4.1	Breakseal Tabs-Inspect Brazing for any pull-away of tabs. Reject if tabs are not tight. Do not pull on tabs this is visual insp. only.	____	____	____
4.2	Breakseal Metalized Band-Inspect for pits, holes, or cracks with a binocular microscope.* Reject if any.	____	____	____
4.3	Anode two to cap ceramic. Inspect for cleanliness. Reject if dirty.	____	____	____
4.4	Anode two flange. Inspect sealing surface for scratches and nicks with a binocular microscope.* Reject if any.	____	____	____
4.5	Anode one to Anode two ceramic. Inspect for cleanliness. Reject if dirty or contains markings of any kind.	____	____	____
4.6	Anode one contact flange. Inspect for sharp edges or protrusions. Reject if any.	____	____	____
4.7	Grid one to anode one ceramic. Inspect for cleanliness. Reject if dirty.	____	____	____
4.8	Grid one contact flange. Inspect for presence of serial numbers or any visual dents. Reject if missing or dented.	____	____	____
4.9	Filament to cathode annular space. Inspect for cleanliness. Reject if dirty.	____	____	____

* 3X magnifier may also be used.

4.10 Filament and cathode contacts. Visually inspect for roundness and concentricity. Reject if obviously out-of-round or dented.

4.11 Measure and record dimensions "A" thru "X" per drawing IPC-C-1055-002 sheet number one. Check if out of tolerance and reject.

DIMENSIONS IN INCHES

	Minimum	Actual	Maximum	✓	A/R	Date	Initial
A	.592		.632				
B	.833		.863				
C	1.105		1.135				
D	1.425		1.455				
E	1.784		1.824				
F	.049		.055				
G	.660		.690				
H	.110		.145				
I	—		1.300				
J	.210		.220				
K	.310		.325				
L	.655		.665				
M	1.194		1.206				
N	1.660		1.668				
O	---		.010 TIR				
P	---		.015 TIR				
Q	---		.025TIR				
R	.250		.325				
S	.045		.125				
T	.120		.130				
U	.031		.124				

					A/R	Date	Initial
V	.062	______	.125	___	______	______	______
W	1 .015	______	1.035	___	______	______	______
X		______	1.323	___	______	______	______

5.0 Static Electrical Tests

5.1 Measure cold resistance of the breakseal band with a Hartman and Braun Wheatstone Bridge. Value ____ohms.

Reject if greater than .5 ohms or less than .1ohms. ______ ______ ______

5.2 Measure cold resistance between cathode and filament with a Hartman and Braun Wheatstone Bridge. Value_____ohms.

Reject if greater than 1.0 ohm or less than o.1 ohm. ______ ______ ______

5.3 Measure resistance between the cathode and grid one with a Simpson Multimeter Model 260 on the 10,000 ohm scale. *

Value __________ ohms.

Reject if less than 10 megohms. ______ ______ ______

5.4 Measure resistance between grid one and anode one with a Simpson Multimeter Model 260 on the 10,000 ohm scale. *

Value __________ ohms.

Reject if less than 10 megohms. ______ ______ ______

5.5 Measure resistance between anode one and anode two with a Simpson Multimeter Model 260 on the 10,000 ohm scale. *

Value ___________ohms.

Reject if less than 10 megohms. ______ ______ ______

5.6 Measure resistance between anode two and the cap with a Simpson Multimeter Model 260 on the 10,000 ohm scale. *

Value ___________ ohms.

Reject if less than 10 megohms. ______ ______ ______

6.0 Hipot DC Testing

6.1 Test Configurations

The configurations for these tests are shown in figures 6.2 and 6.3.

* RCA model WV98C VTVM on the one megohm scale may also be used.

The unit being tested shall be mounted in test fixture EE65-1, and contained in one atmosphere of dry sulphur hexaflouride gas (SF_6).

6.2 Anode Two to Anode One Hipot Testing

Test configuration in Figure 6.2. Test Procedure:

Hipot in dry SF_6 environment at 1 atmosphere pressure

Increase voltage slowly to 20 kv then proceed in 2 kv steps

Hold voltage for 30 seconds without breakdown at each step from 20 - 28 kv.

At 30 kv hold voltage for 5 minutes. After this period if a gun will not hold 30 kv for at least 30 seconds, it will be rejected.

During 5 minute run record voltage and current every 1 minute and note the number of breakdowns, if any.

During 30 second run record voltage and current at the end of period. Also record the number of breakdowns at each level.

Voltage (KV)	Current (μ amps)	No. of Breakdowns
20	________	________
22	________	________
24	________	________
26	________	________
28	________	________
30	________	________

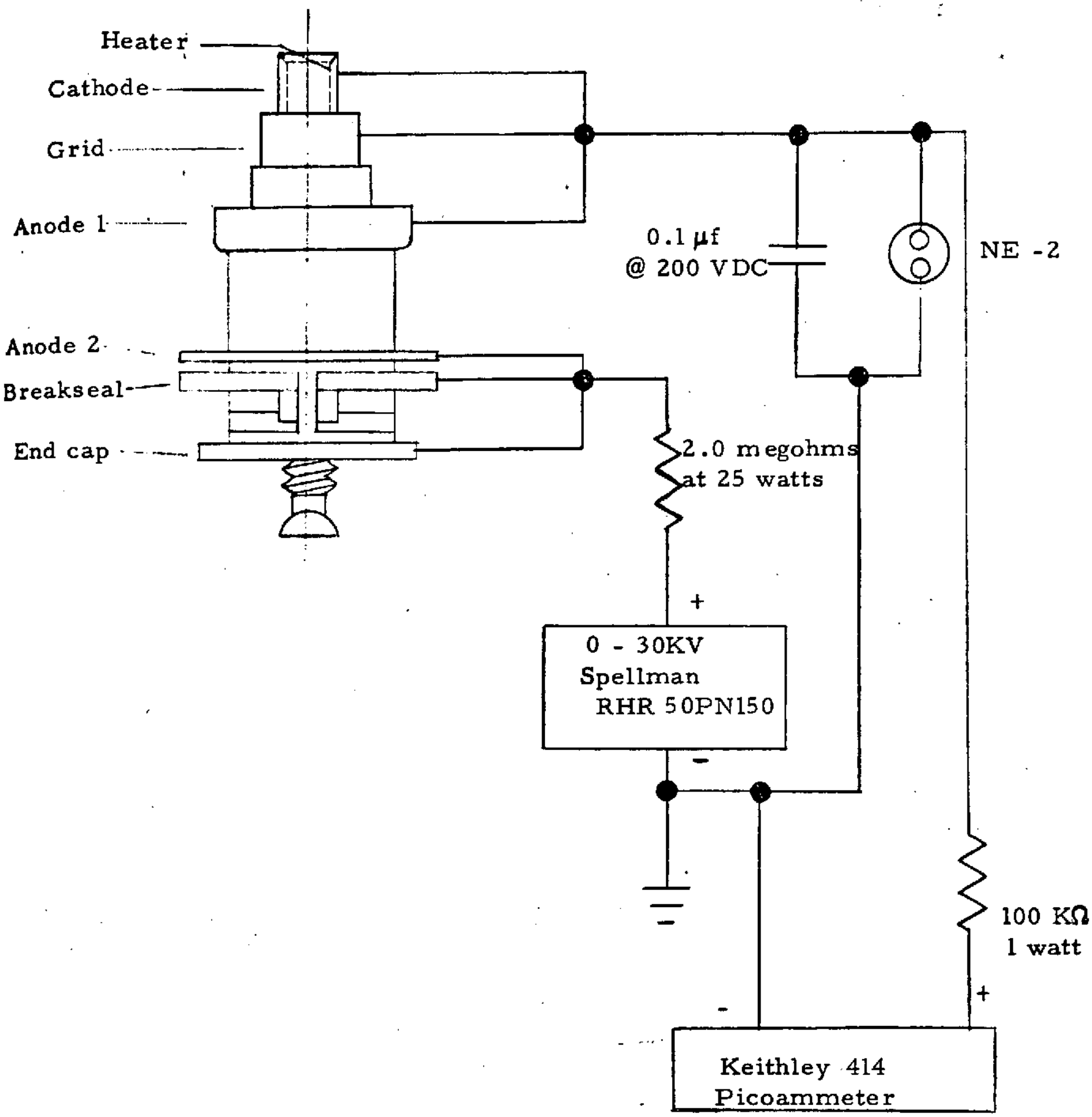
Minute (5 min.run)	Current (μ amps)	No. of Breakdowns
0	________	________
1	________	________
2	________	________
3	________	________
4	________	________
5	________	________

Final 30 second test:

No. of breakdowns ________________

Reject if any

A/R	Date	Initial



Anode Two / Anode One   Hipot Configuration

FIG. 6.2

6.3 Anode One to Grid One Hipot Testing

Test configuration in Figure 6.3. Test Procedure:

Hipot in dry SF_6 environment at 1 atmosphere pressure.

Increase voltage slowly to 1 kv then proceed in 200v steps

Hold voltage for 30 seconds without breakdown at each step from 1 to 2 kv.

At 2 kv hold voltage for 5 minutes. After this period if a gun will not hold 2 kv for at least 30 seconds, it will be rejected.

During 5 minute run record voltage and current every 1 minute and note the number of breakdowns.

During 30 second run record voltage and current at the end of period. Also record the number of breakdowns at each level.

Voltage (KV)	Current (nA)	No. of Breakdowns
1.0	______	______
1.2	______	______
1.4	______	______
1.6	______	______
1.8	______	______
2.0	______	______

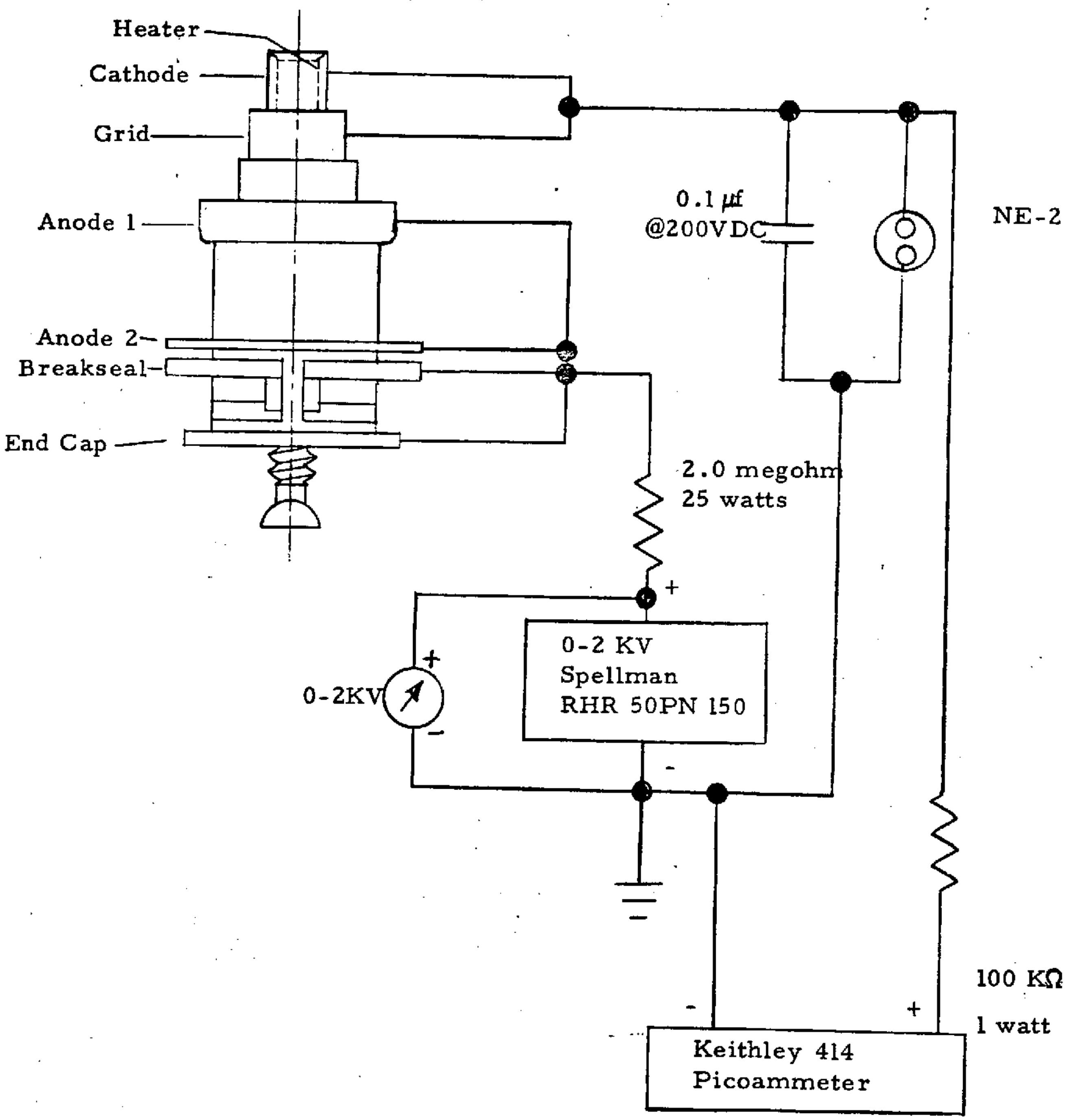
Minute (5 Min. Run)	Current (nA)	No. of Breakdowns
0	______	______
1	______	______
2	______	______
3	______	______
4	______	______
5	______	______

Final 30 second test:

No. of breakdowns ______.

Reject if any

______ A/R ______ Date ______ Initial



Anode One / Grid One Hipot Configuration

FIG. 6.3

7.0 Gun Transfer Characteristic Measurements

7.1 Test Configurations

The configuration for these tests is shown in figure 7.1. The unit being tested shall be mounted in test fixture EE 65-1, and contained in one atmosphere of dry sulphur hexaflouride gas (SF_6).

7.2 Filament Current Tests

Energize filament and determine filament current at 7.5 volts. Accept if current falls between 1.425-1.575 amps. Reject if current is less than 1.40 or more than 1.60 amps. Reject and hold if current is 1.4-1.425 or 1.575-1.6 for review by engineering and Q.C.

Current______________ Amps. ________ A/R ________ date ________ initial

7.3 Grid One Characteristic Measurement

Obtain oscilloscope record of plate-current-grid voltage characteristics for the following conditions with filament at 7.5 volts.

a) Anode two- cathode voltage 5.0KV ±10%.
   Anode one - cathode voltage 250 V ± 5%.

b) Anode two - cathode voltage 10.0KV ± 10%.
   Anode one - cathode voltage 500V ± 5%.

c) Anode two - cathode voltage 20.0KV ± 10%.
   Anode one - cathode voltage 1000V ± 5%.

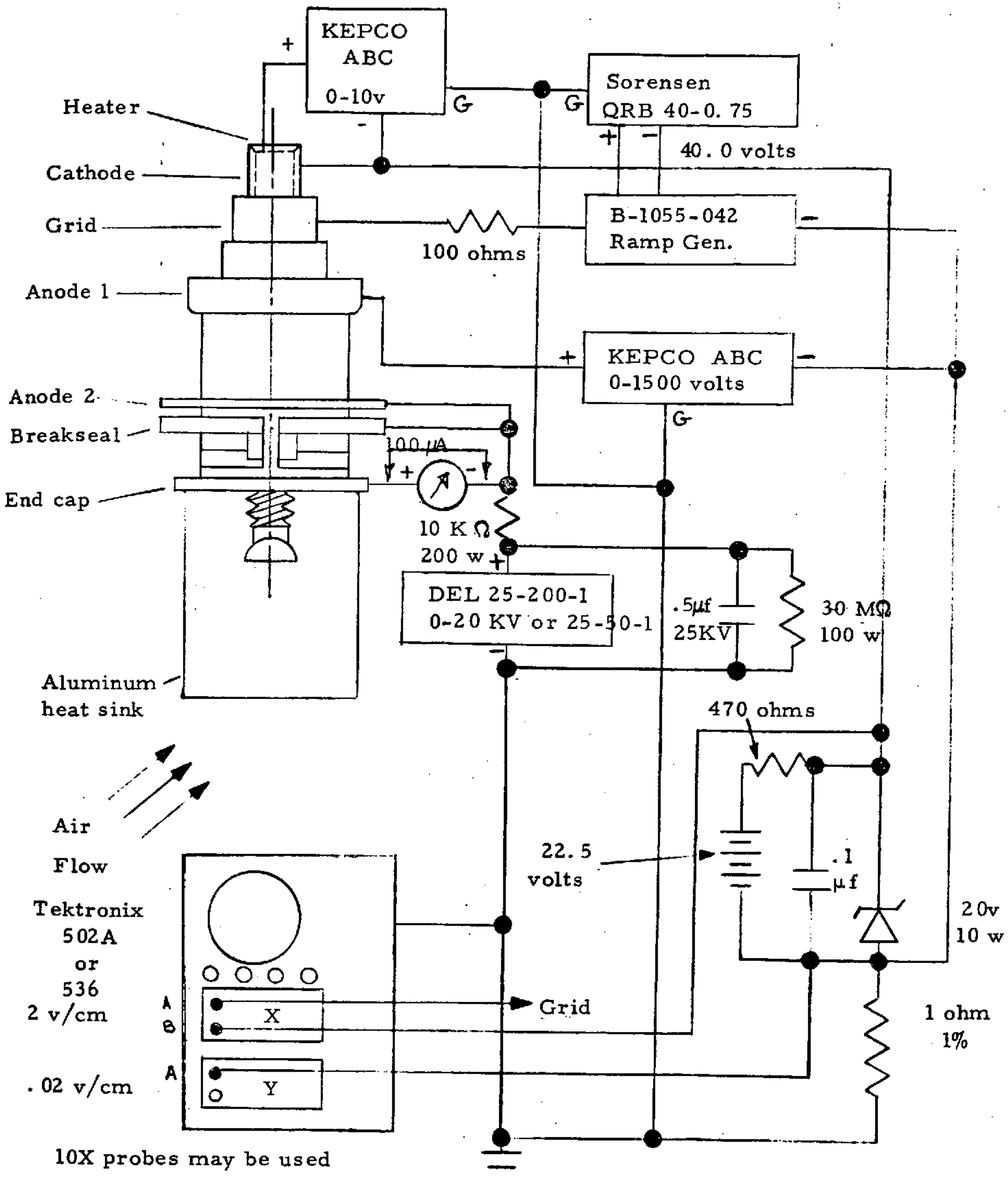
Test performed by manually triggering the 30 volt ramp generator. Do not exceed 10 sweeps on the gun in 1 minute. Be sure that the end cap is properly heat sinked as indicated in figure 7.1.

NOTE: For grid control characteristics to be acceptable at 20KV:

A. The grid bias required to obtain 100 ma return current must fall between -2.5 volts and +.5 volts.______Volts @ 100 mA

B. At 100 ma the mutual conductance (g_m) of the tube must fall between 18,200 and 24,600 micromhos. This number is derived by taking from the 20 KV photograph the grid voltage at 80mA (V_{80}) and the grid voltage at 100 mA (V_{100}) and inserting in the following formula:

$$g_m = \frac{20,000}{V_{100} - V_{80}} = \_\_\_\_\_\_ \ \mu\text{mhos}$$



Gun Transfer Charateristic Test Setup
FIG. 7.1

X____ V/cm

Y____mA/cm

5.0 KV

X____V/cm

Y____mA/cm

10.0KV

X_____V/cm

Y_____mA/cm

20.0KV

_____ A/R _____ date _____ initial

7.4 Grid One Cut-off Test

Test performed by switching B-1055-042 ramp generator to cut-off position. Also remove shorting clip from 100 μ amp meter.
Record leakage current under conditions described in section 7.3 (c). Reject if greater than 5 μA.

Current __________________ μA

_____ A/R _____ date _____ initial

Return switch on B-1055-042 ramp generator to ramp position and shorting clip across 100 μamp meter. Initial after completion.

_____ date _____ initial

8.0 Final Inspection

8.1 Remove from bench checkout unit and inspect for any changes in appearance - cracks, chips, tracks, evidence of overheating, etc., using a binocular microscope.*

Final Acceptance

Inspector_________________________A/R

Quality__________________________A/R

Program__________________________A/R

8.2 Replace guns in their original boxes and mark the package accepted, or rejected. If rejected explain reasons in a few words. Inspector should sign and date each box upon completion of the above.

* 3X magnifier may also be used.

APPENDIX B

FAILED COMPONENT PART ANALYSIS REPORT

(COMPLETE THIS FORM IN BLOCK LETTERS)

3. REPORT NUMBER
11084B

1. DATE
8-31-70

2. REFERENCE
Contract NAS 9 - 10399 W/A 89107

COMPONENT PART NAME
Electron Gun Model ML-EE65-1 Serial #1

5. REPORTED REMOVAL CAUSE
Grid-cathode short, increase in filament current to 2 amps

6. FAILURE ANALYSIS METHOD EMPLOYED
Gun was opened by activation of the breakseal after a telephone conversation with W. H. Merritt of Machlett Laboratories for visual observation at the suggestion of Mr. Merritt.

7. FAILURE ANALYSIS RESULTS
At IPC on 8-31-70
1. Holes in grid structure just inside cathode perimeter.
2. Melted grid wires shorted to cathode surface.
3. Cathode surface dark grey instead of normal white.

At Machlett on 9-1-70
1. Silver plating missing from end of pinch-off on the evacuation tubing.
2. Hole found in the pinch-off visible with the unaided eye.

8. COMPONENT PART FAILURE CAUSE
Failure caused by overheating of the pinch-off due to excessive energy dissapation as a result of the test procedure levels. Temperatures greater than 800°C were present at the pinch-off as evidenced by the complete lack of silver plating. The development of an air leak resulted in the symptoms indicated in item 5, above.

WAS COMPONENT PART FAILURE CAUSE CONSISTENT WITH MODULE OR SYSTEM FAILURE/MALFUNCTION SYMPTOMS?
YES ☐ NO ☐ NEOF ☐ (No Evidence of Failure) Not applicable

10. PRIMARY OR SECONDARY COMPONENT PART FAILURE?
PRIMARY ☒ SECONDARY ☐ NEOF ☐

11. COMPONENT PART FAILURE RESPONSIBILITY

DESIGN	☐	TEST ERROR	☒
FABRICATION	☐	NORMAL WEAROUT	☐
PART	☐	EXTERNAL	☐
WORKMANSHIP	☐	UNKNOWN	☐
HANDLING	☐	NONE	☐

OTHER

12. CORRECTIVE ACTION RECOMMENDED
1. Test procedure I/ML-EE65-1 section 7.3 be changed to reduce energy dissipation by at least one hundred to levels attained by Machlett Labs during pulse testing (the order of 10 joules per test not to exceed 1000 joules per minute heat sinked). 2. Care to be taken in design of test and check circuits and procedures to insure safe operation sealed with 100% confidence.

13. REMARKS
Failure occurred during testing under section 7.3 of inspection plan I/ML-EE 65-1

14. FAILED COMPONENT PART ANALYST'S SIGNATURE
William E Slack Approved E. E. Hanna

FAILED COMPONENT PART ANALYSIS REPORT

Operational Considerations

Ref: Failed Component Part Analysis Report 11084B

A Critical design review was held 3 September 1970 to ascertain whether the component (electron gun EE 65-1 prototype) test failure could affect the operation of deliverable payload during ground check-out and launch.

Attendees: Hansen, James, Starks, Weinschenk, Macklin

Items of Discussion:

1. A modification of the gun cap configuration was discussed to prevent the beam from impinging on the pinch off tube wall thin section.

   1.1 The impact of a change would not prevent thermal failure of the gun as the total thermal heat sink capability of the gun cap is not great enough to dissipate the energy present in full power test erroneously exceeding the 10 joule maximum energy level.

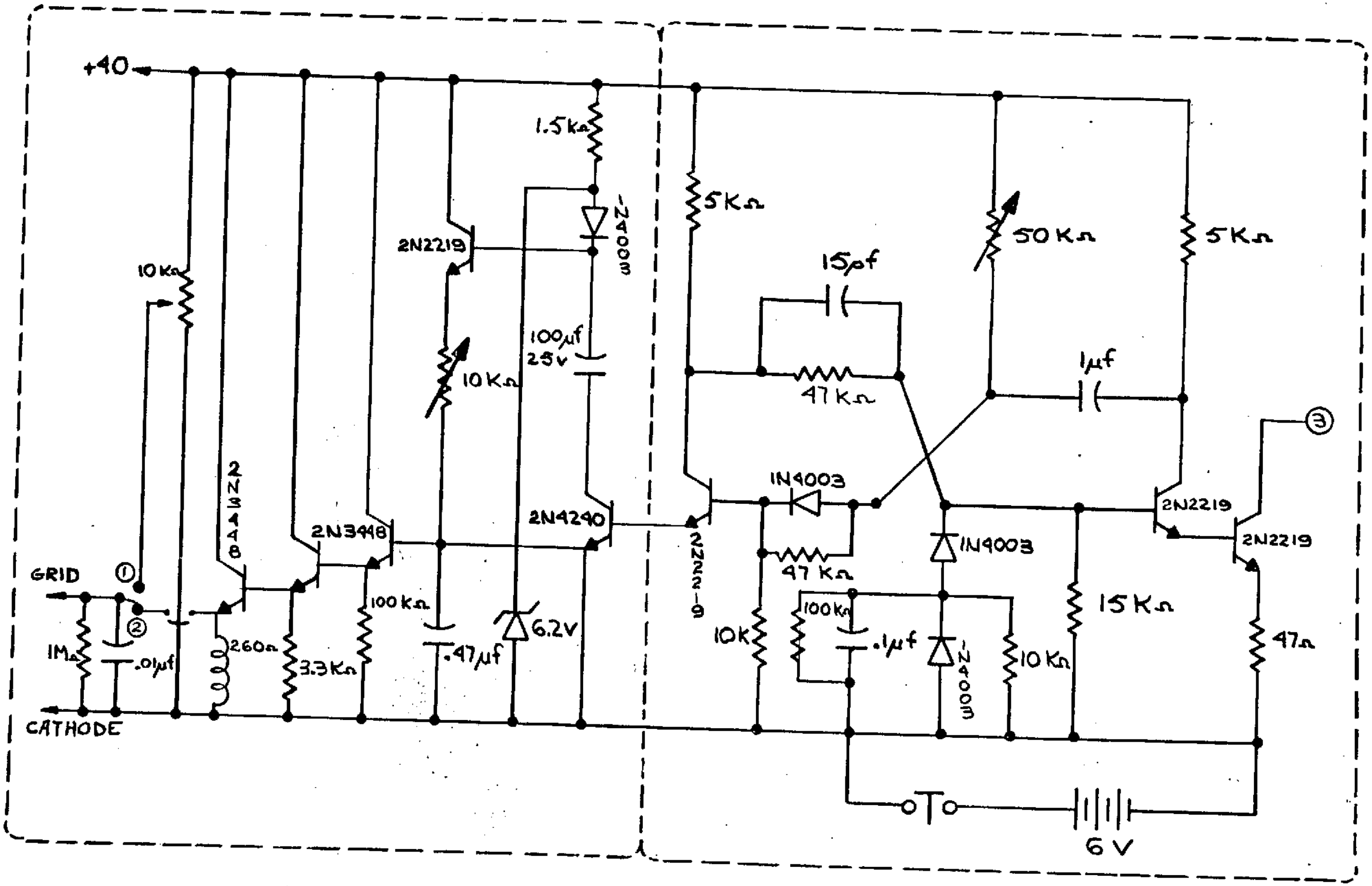
2. Action taken to prevent operational failure during ground check out.

   2.1 Design of a fail -safe ground check out program is being investigated.

   2.2 Implementation of the fail safe measure into existing program to be accomplished.

   2.3 No design change to gun cap is recommended or forthcoming at this time.

APPENDIX C

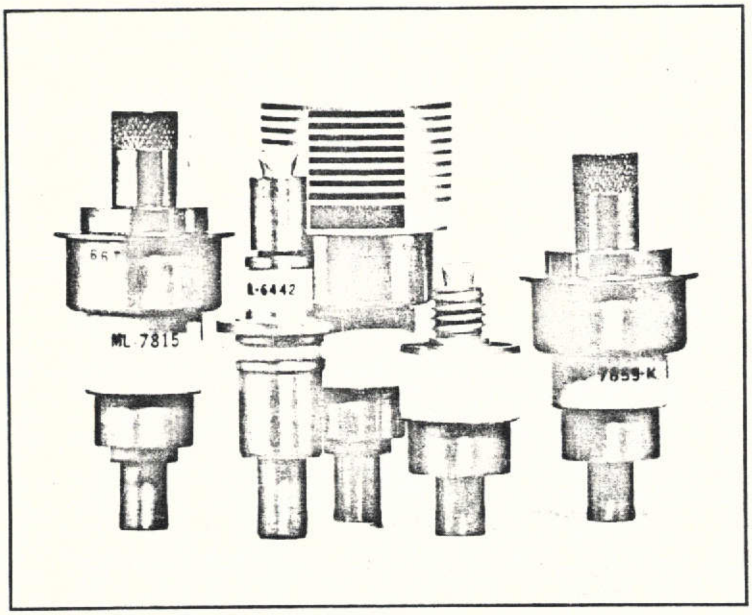


Appendix C - Grid Sweep Circuit

APPENDIX D

ATTACHMENT #4

The Machlett Laboratories, Inc. • 1063 Hope Street
Stamford, Conn. 06907 • Tel. 203-348-7511 • TWX 710-474-1744



ISSUED 10-68

Application Notes UHF Triodes Extended Life AL Series Tubes for Airline Operation

MACHLETT

General

The Machlett AL series of planar triodes for low-maintenance, low down-time airline operation are produced and tested to premium standards to insure extended life performance. This long life operation is a result of a combination of many factors including: stringent application of newly defined quality control standards; the use of the Machlett Phormat cathode employing improved cathode material; application of a testing schedule going well beyond military specifications; use of anti-corrosion plating (gold) to ensure excellent contact life and performance. Covered by an extended life warranty, these tubes are mechanically and electrically superior to the standard types, . . . in addition they will outperform the standard types under long-life conditions (i.e., reduced heater voltage) by a wide margin.

Filament Voltage: 5.7 V Operation

Any tube that will pass MIL-E specifications will operate at heater voltages in excess of 6.0 volts. Only those tubes with excellent cathode activity will operate at rated power for extended periods at less than 6.0 volts. The Machlett AL series tubes operate at 5.7 volts, nominal. It is imperative that this voltage level be maintained to insure that cathode temperatures are held at the level for which the heater design has been optimized. *Only by operating the AL series tubes at 5.7 volts, nominal, will the extended life capability be realized.* Factors defining the performance of AL series cathodes are described in the paragraph entitled "Phormat Cathode".

Anti-Corrosion Plating

To minimize contact loss and substantially eliminate arcing due to corrosion effects the Machlett AL series planar triodes are gold plated. Both tube and contact life will be enhanced, particularly where conditions favorable to corrosion exist.

Phormat Cathode

The Machlett Phormat cathode (a matrix cathode) employs a porous coating which provides an arc-resistant surface. Its high voltage stability, therefore, is excellent and its ability to maintain a clean tube interior is correspondingly good. Field gradients of 135 kV/cm and higher have been impressed between the grid and anode of the ML-7815 and ML-7815/AL and also to comparable tubes not using the Phormat cathode. While the standard cathodes were almost completely destroyed the Phormat cathode showed only a few arc marks — and yet still maintained its operating capability. (Modulator tubes such as the planar triode ML-8533 carry an 8 kVdc plate voltage rating.)

Deposited vs Sprayed Cathodes

The Phormat cathode has been in use in UHF planar tube types since its development by Machlett Laboratories in 1960. The high reliability of this cathode under extreme voltage conditions has made possible its use in grid pulsed applications. The use of this cathode type at high frequencies, where transit time increases the back-bombardment of the cathode, gives the Phormat cathode great advantage as compared with the standard sprayed cathode.

The structure of the cathode consists of a metal base on which a porous layer of nickel is deposited by electrolytic and cataphoretic deposition*. This cathode is sprayed as a regular emitter, but it presents a rough surface where the triple carbonate coating (BaSrCa) CO_3 can more easily obtain the required donors increasing the uniformity of emission of the layer, thereby avoiding the "patchy" emission characteristic of standard emitters. This nickel "sponge" provides at the same time a very fast heat transfer, reducing the effects of the backbombardment on the cathode at high frequencies.

Another major advantage of the Phormat cathode in pulsed applications is its ability to reduce the adverse effects of arcing within the tube. When arcing occurs in a standard sprayed cathode, large segments of the cathode layer tend to lift from the metal base resulting in catastrophic failure whereas in the Phormat structure only a localized area is affected and tube life is unimpaired.

Quality Control and Tube Testing

The Quality Control operation associated with the Small Power Tube Product Line — which produces the Airline Quality planar triodes — operates more as a continuous process control than a check and inspect procedure. Under a continuous feedback control system are, for example, the cathode components (the nickel matrix, which is deposited on the emitter surface); the carbonates, (which are sprayed on the nickel base and later converted to the emitting surface); and the final cathode processing. The nickel of the nickel matrix powder is analyzed and certified to be of the high purity level required. Carbonates are spectrographically analyzed and certified for highest purity levels. In addition, the associated solvents and binders are specifically formulated and controlled to meet the Phormat cathode requirements. Final processing of the cathode is extremely critical, and must take place in a non-reactive atmosphere. In addition, bake and exhaust schedules (tube outgassing) must be precisely performed to assure internal cleanliness of the tube.

Tube testing of the Airline Quality planar triodes has been set up as a separate program, itself a result of field life history and a comprehensive appraisal of the actual conditions under which tubes operate. To this end a series of definitive tests were scheduled for each AL tube to reflect environmental conditions and be predictive with regard to tube life under these conditions. Since failure mode analysis had indicated that cathode depletion was the typical cause for tube removal, test emphasis lies in the direction of assuring long term cathode activity. Grid-pulsed rf amplifier output vs variation in heater voltage and short and long pulse duration at reduced heater voltage provide two critical tests for cathode performance. Figure 1 describes a plot of a typical MIL-E specification 7815 and an ML-7815/AL tube showing the extended performance characteristics of the latter. Figure 2 shows comparable oscilloscope traces of the 4500 μsec pulse determining cathode activity under extremely high loading. As is evident, the ML-7815/AL pulse shows negligible current droop. Static tests to tightened amplification (mu) and transconductance (gm) specifications are performed as well as tests for plate current cut-off, interelectrode capacity and grid characteristics. Mechanical and high g shock testing are done on a sampling basis.

*"Simultaneous Cataphoretic and Electrolytic Deposition of Nickel for Cathode Bases of Reliable Electron Tubes", by P. F. Varadi and K. Ettre, *Journal of the Electrochemical Society,* Vol. 109, No. 4, April 1962.

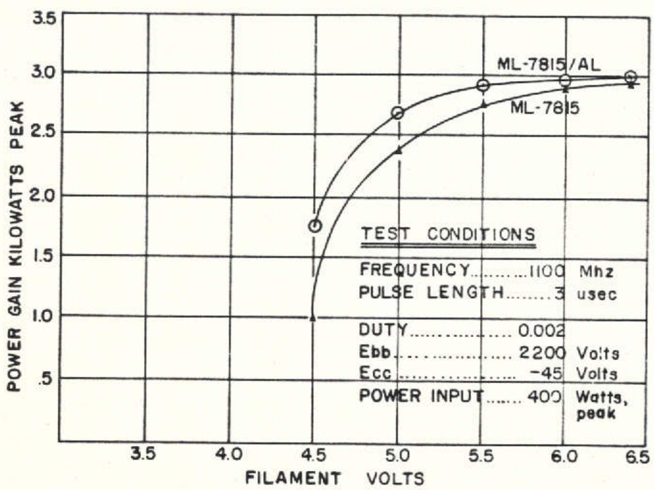


Figure 1 — Grid Pulsed RF Amplifier Output vs Heater Voltage.

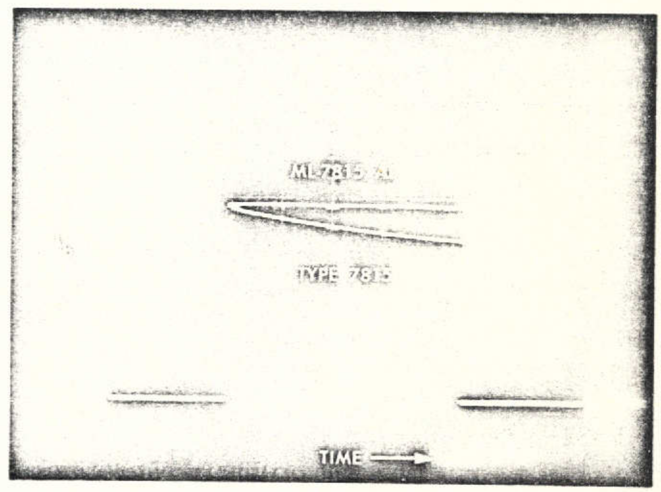


Figure 2 — Long Pulse Performance of Standard ML-7815 vs ML-7815/AL Tube.

ST-2505 5M
Printed in U.S.A.

APPENDIX E

Test Report No. NT-7523-11

No. of Pages 12

Contract # NAS-9-10399

Report of Test on

ELECTRON GUN

Environmental Testing

for

Ion Physics Corporation

Associated Testing Laboratories, Inc.

Burlington, Massachusetts

Date September 16, 1970

	Prepared	Checked	Approved
By	E. R. Mencow	R. Borghetti	E. E. Kulcsar
Signed	E R Mencow	R. Borghetti	E E Kulcsar
Date	9/21/70	9-18-70	[illegible]

SURVEILLANCE BY [illegible] QA DCASA BOSTON

21Sep70 DCRB 20N

Administrative Data

1.0 Purpose of Test:

To evaluate the performance of the Electron Gun when subjected to Environmental Testing in accordance with the referenced Specification and Procedures of this Test Report.

2.0 Manufacturer:

Ion Physics Corporation
South Bedford Street
Burlington, Massachusetts 01803

3.0 Manufacturer's Type or Model No.:

EE65-1

4.0 Drawing, Specification or Exhibit:

In accordance with written and verbal instructions from Ion Physics Corporation.

5.0 Quantity of Items Tested:

One (1) (S/N 3)

6.0 Security Classification of Items:

Unclassified

7.0 Date Test Completed:

September 14, 1970

8.0 Test Conducted By:

Associated Testing Laboratories, Inc.
NEW ENGLAND DIVISION

9.0 Disposition of Specimens:

Returned to Ion Physics Corporation

10.0 Abstract:

The submitted Electron Gun was subjected to Sinusoidal Vibration over the frequency range of 20 to 2000 Hz at levels up to ±6g's peak. The unit was vibrated in three mutually perpendicular axes. There was one sweep up from 20 to 2000 Hz in each axis. There was no visible damage incurred to the Electron Gun as a result of the Sinusoidal Vibration Test.

10.0 Abstract (continued)

The Electron Gun was subjected to Random Frequency Vibration Testing over the range of 20 - 2000 Hz at a PSD Level of $0.05g^2/Hz$ and an overall level of 10g's rms. The unit was subjected to the Random Vibration for a period of 10 seconds in each of its 3 mutually perpendicular axes. At the conclusion of the Random Vibration Test, there was no visible damage incurred to the Electron Gun.

The Electron Gun was subjected to a Shock Test in each of its 3 mutually perpendicular axes. A total of 6 blows was delivered to the unit, 1 in each direction of each axis. Each shock pulse approximated a half sine wave with a peak amplitude of 15g's and 15 millisecond time duration. There was no visible damage incurred to the Electron Gun as a result of the Shock Test.

SINUSOIDAL VIBRATION TEST

TEST PROCEDURE

The submitted Electron Gun was subjected to a Sinusoidal Vibration Test in accordance with written and verbal instructions from a Representative of Ion Physics Corporation. The following is a description of the test as it was performed.

The Electron Gun was securely attached to its Vibration Test fixture, which was then attached to the table of the Vibrator. The Electron Gun was then subjected to Sinusoidal Vibration over the frequency range of 20 to 2000 Hz at the levels given below:

TABLE I

Frequency (Hz)	Amplitude
20 - 500	±1g
500 - 2000	±6g's

The frequency range from 20 to 500 Hz was swept up in approximately 30 seconds and the frequency range from 500 - 2000 Hz was swept up in approximately 30 seconds. There was no return sweep.

The above procedure was performed in each of the unit's 3 mutually perpendicular axes. The Electron Gun was examined for damage after vibration in each axis.

TEST RESULTS

There was no visible damage incurred to the Electron Gun as a result of the Sinusoidal Vibration test.

RANDOM VIBRATION TEST

TEST PROCEDURE

The Electron Gun was subjected to Random Frequency Vibration Testing in accordance with written and verbal instructions from an Engineering Representative of Ion Physics Corporation. The following is a description of the test as it was performed.

The Electron Gun was secured to the Vibrator as previously described in the Sinusoidal Vibration Test Procedure. The unit was then subjected to the following Random Vibration Test:

Test Level

Frequency (Hz)	PSD Level (g^2/Hz)
20 - 2000	0.05

Overall Level = 10g rms

The above Random Vibration Test Levels were applied in each of three mutually perpendicular axes.

Prior to mounting the specimen to the Vibration Test fixture, equalization of the Random System was accomplished by means of a System containing 85 parallel band-pass filters with individual attenuators for spectrum shaping. Each filter had a maximum bandwidth of 25 Hz. The System also contained Monitoring Circuits with power spectral density meters which read directly in g^2/Hz. The System was first set-up in the closed loop mode. After programming in the specified test levels, the test spectrum was applied to the Shaker System. Where necessary, resetting of equalization controls was performed at those frequencies where the applied test level had deviated from that specified. The output of the Control Accelerometer with its associated normalizing filters was applied to the input of a Spectral Density Analyzer/Tracking Filter. The recorded power spectral density was displayed on an X-Y Plot. The tolerance of the displayed power

TEST PROCEDURE
(continued)

spectral density level was ±3db. The filters used for analyzing the random frequency test spectrum was as follows:

A. 20 Hz - from 20 to 100 Hz.

B. 50 Hz - from 100 to 2000 Hz.

After having assured that the test levels were within the stated tolerances, the System was shut-down and the Electron Gun was mounted to the test fixture.

The unit was subjected to the Test Levels for a period of 10 seconds in each of three mutually perpendicular axes.

The Electron Gun was examined for evidence of physical damage upon completion of each Random Vibration Exposure.

TEST RESULTS

There was no visible damage incurred to the Electron Gun as a result of the Random Vibration Test.

SHOCK TEST

TEST PROCEDURE

The Electron Gun was subjected to a Shock Test in accordance with written and verbal instructions from Ion Physics Corporation. The following is a description of the test as it was performed.

The Electron Gun was securely mounted to its fixture which, in turn, was mounted to the carriage of the Shock Machine. The unit was then subjected to a total of 6 blows, 1 in each direction of three mutually perpendicular axes. The magnitude of the shock pulse was 15g's, the time duration was 15 milliseconds, and the wave form was half sine wave. At the end of the test the unit was examined for external mechanical damage.

TEST RESULTS

There was no visible damage incurred to the Electron Gun as a result of the Shock Test.

LIST OF APPARATUS

Item	Manufacturer	Model No.	Accuracy	Calibration Date	Calibration Date Due
Vibration System	MB Electronics	C-60	±2%Freq. ±5%Ampl.	7-9-70	10-9-70
Accelerometer	Endevco Corporation	2215-E	±5%	7-24-70	10-24-70
Automatic Spectral Density Equalizer/Analyzer	Ling Electronics	ASDE-80	±5%	8-20-70	9-20-70
Analyzer Console	Associated Testing Laboratories, Inc. (NED)	135	±5%	9-3-70	10-3-70
Timer	Dimco-Gray Co.	165	±1sec/hr	7-13-70	1-13-70
Shock Machine	Avco Corporation	110 Model -3	N/A	Before Use	
Shock Console	Associated Testing Laboratories, (NED)	333	±5%	7-10-70	10-10-70
Oscilloscope	Tektronix	564	±3%	6-26-70	9-26-70
Camera	Hewlett-Packard	196A	N/A	N/A	N/A

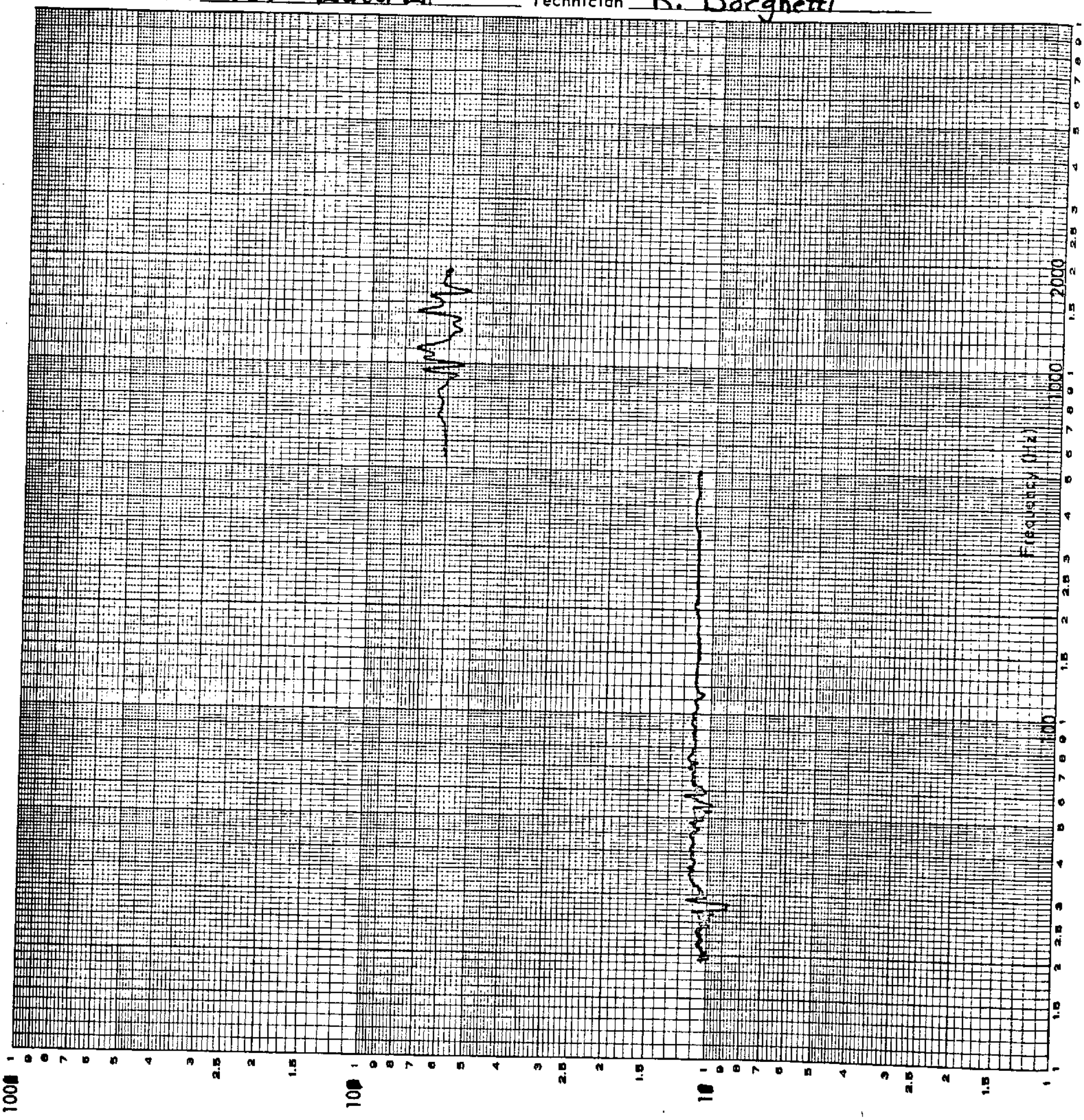
Associated Testing Laboratories, Inc.
Wayne, New Jersey 07470
Burlington, Massachusetts 01803

SINUSOIDAL VIBRATION ANALYSIS

Job Number NT-7523 Customer Ion Physics Corporation Date 9-14-70

Specimen P/N EE65-1 Specimen S/N 3 Test Temp. Room Ambient

Axis 1st Lateral Technician R. Borghetti



"g" Level

Associated Testing Laboratories, Inc.

Wayne, New Jersey 07470

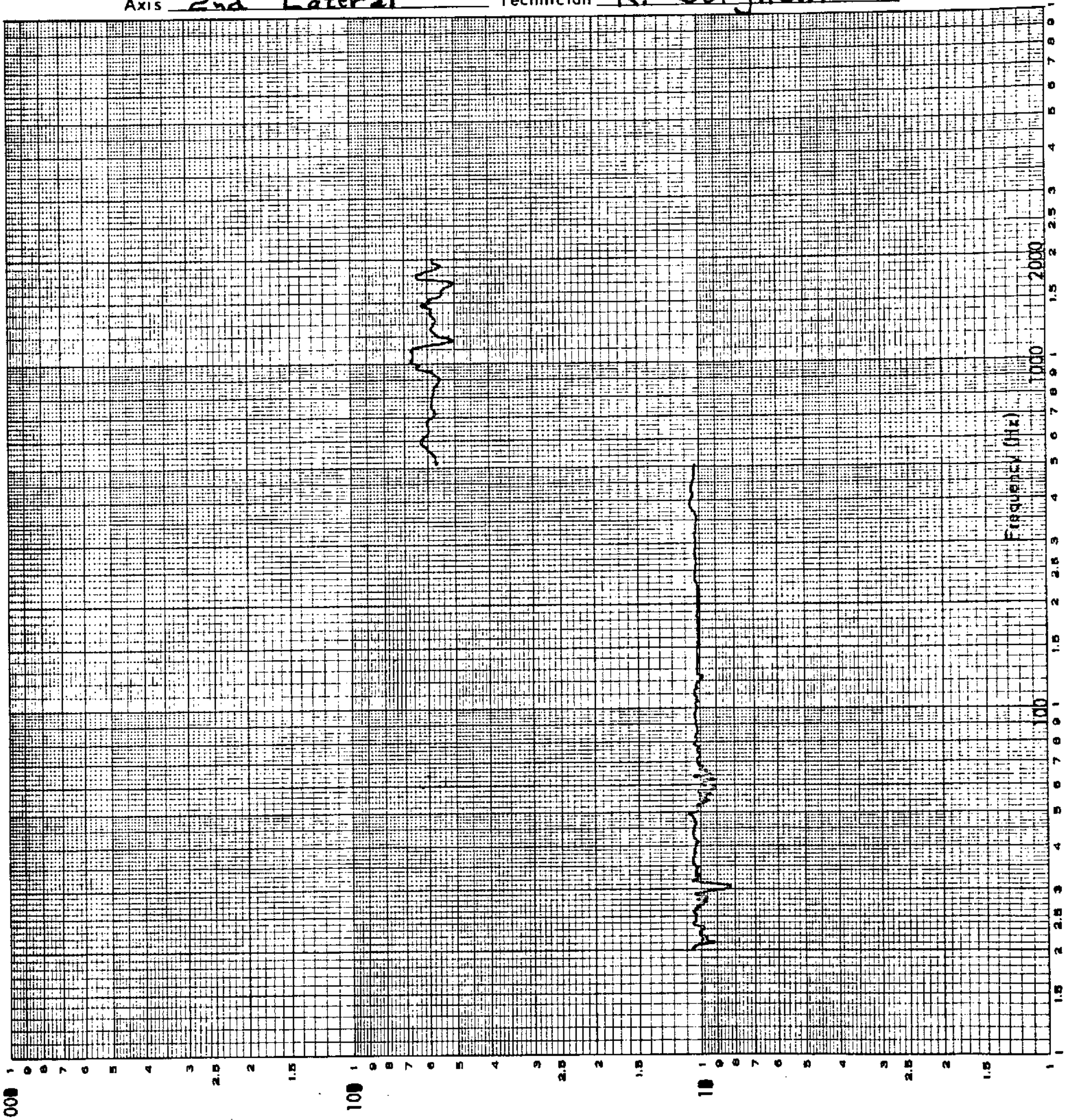
Burlington, Massachusetts 01803

SINUSOIDAL VIBRATION ANALYSIS

Job Number NT-7523 Customer Ion Physics Corporation Date 9-14-70

Specimen P/N EE65-1 Specimen S/N 3 Test Temp. Room Ambient

Axis 2nd Lateral Technician R. Borghetti



"g" Level

Associated Testing Laboratories, Inc.

Wayne, New Jersey 07470

Burlington, Massachusetts 01803

FORM NO. 9-51

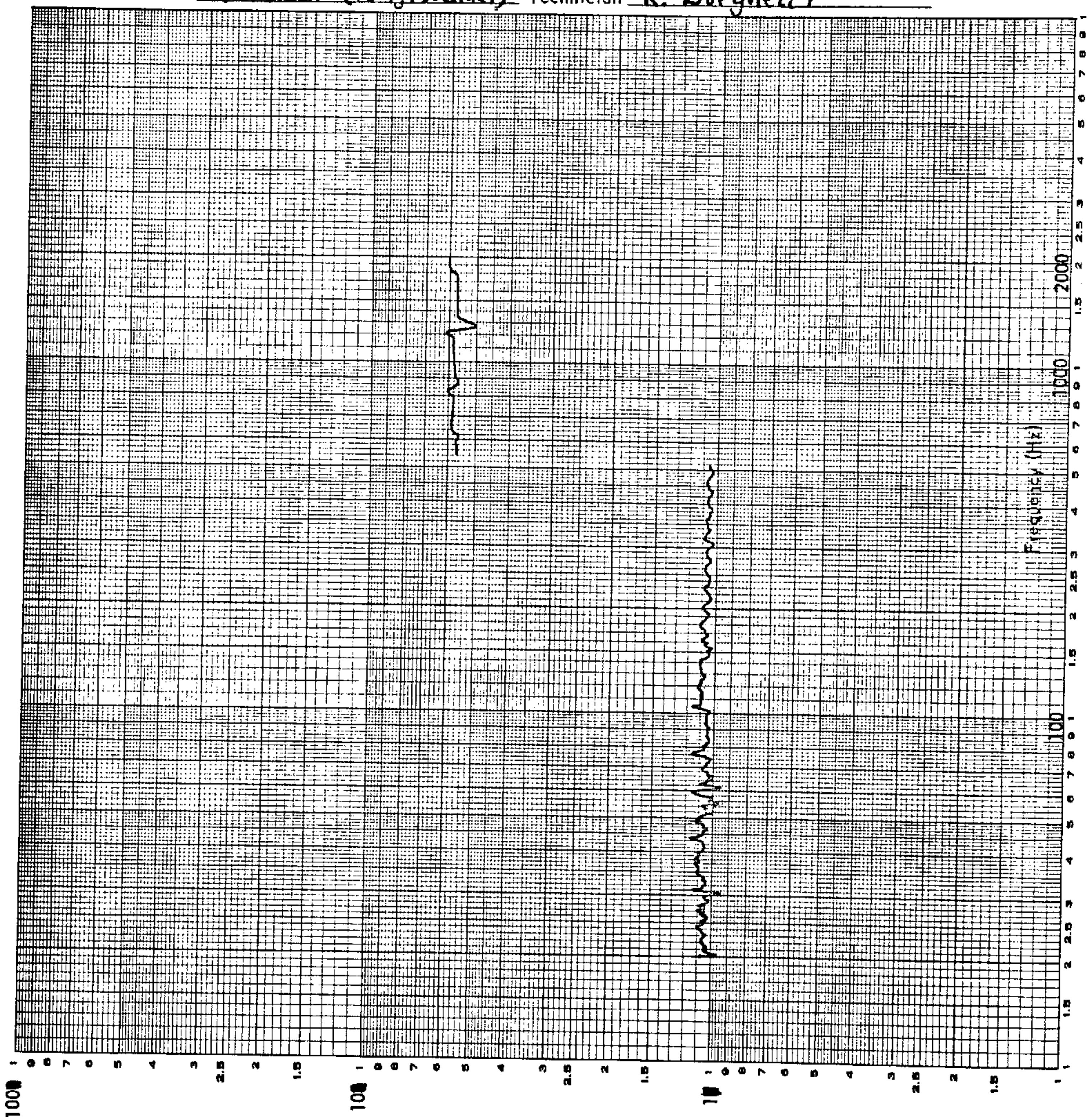
Report No. NT-7523-11 Figure ______ Page 9

SINUSOIDAL VIBRATION ANALYSIS

Job Number NT-7523 Customer Ion Physics Corporation Date 9-14-70

Specimen P/N EE65-1 Specimen S/N 3 Test Temp. Room Ambient

Axis Vertical (longitudinal) Technician R. Borghetti



Associated Testing Laboratories, Inc.

Wayne, New Jersey 07470

Burlington, Massachusetts 01803

FORM NO. 9-51

Report No. NT-7523-11 Figure ______ Page 10

RANDOM VIBRATION ANALYSIS

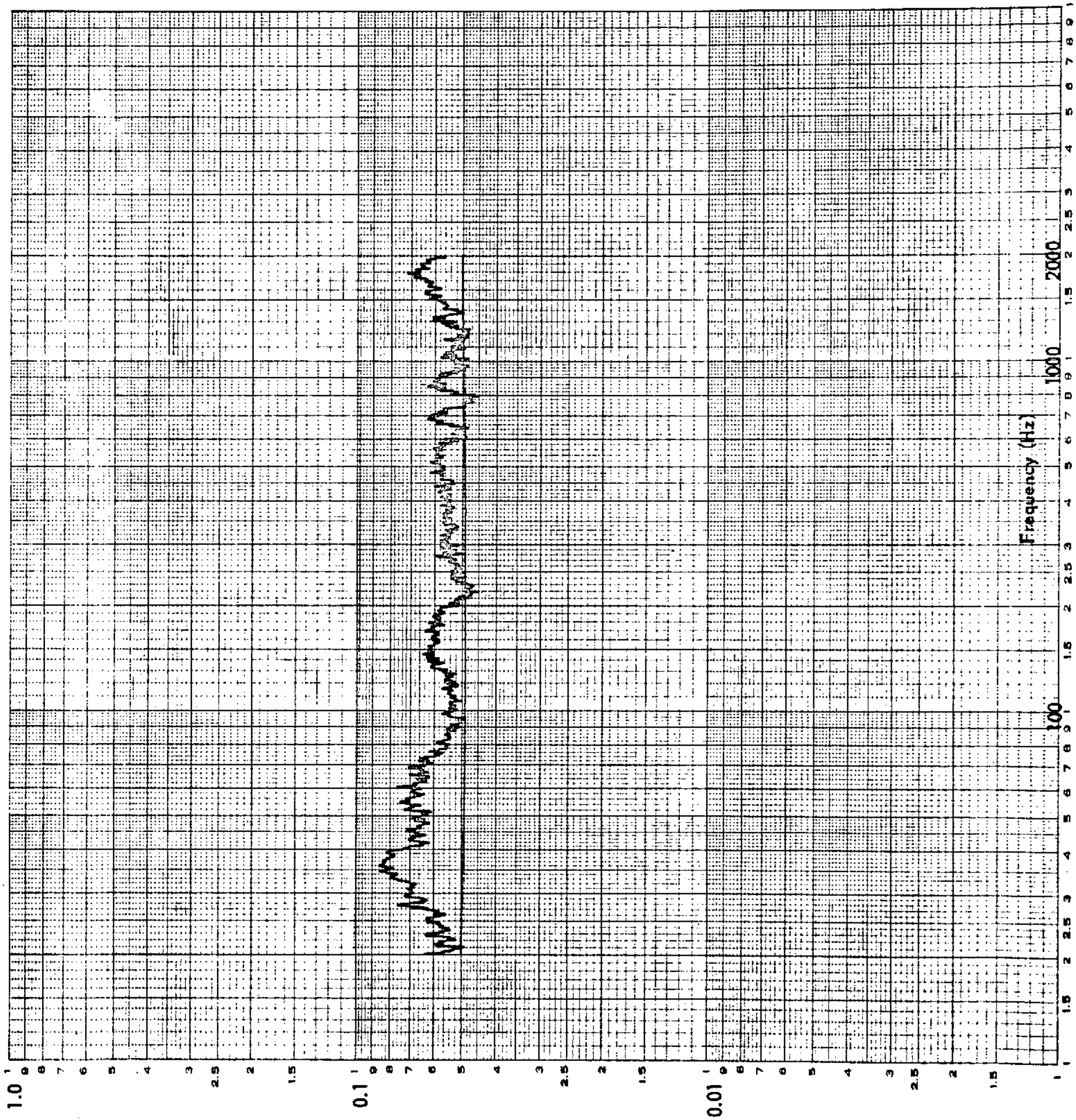
Job Number NT-7523 Customer Ion Physics Corp. Date 9-14-70

Specimen P/N EE 65-1 Specimen S/N 3 Test Temp. Room Ambient

Bw. Analyzed Filter No. 1 20 to 100 Hz, Bw. Analyzed Filter No. 2 100 to 2000 Hz

Analyzing Filter No. 1 20 Hz Analyzing Filter No. 2 50 Hz

Vibration Axis Vertical (Longitudinal) Technician R. Borghetti



Spectral Density Level X 10 - (g^2/Hz)

Associated Testing Laboratories, Inc.

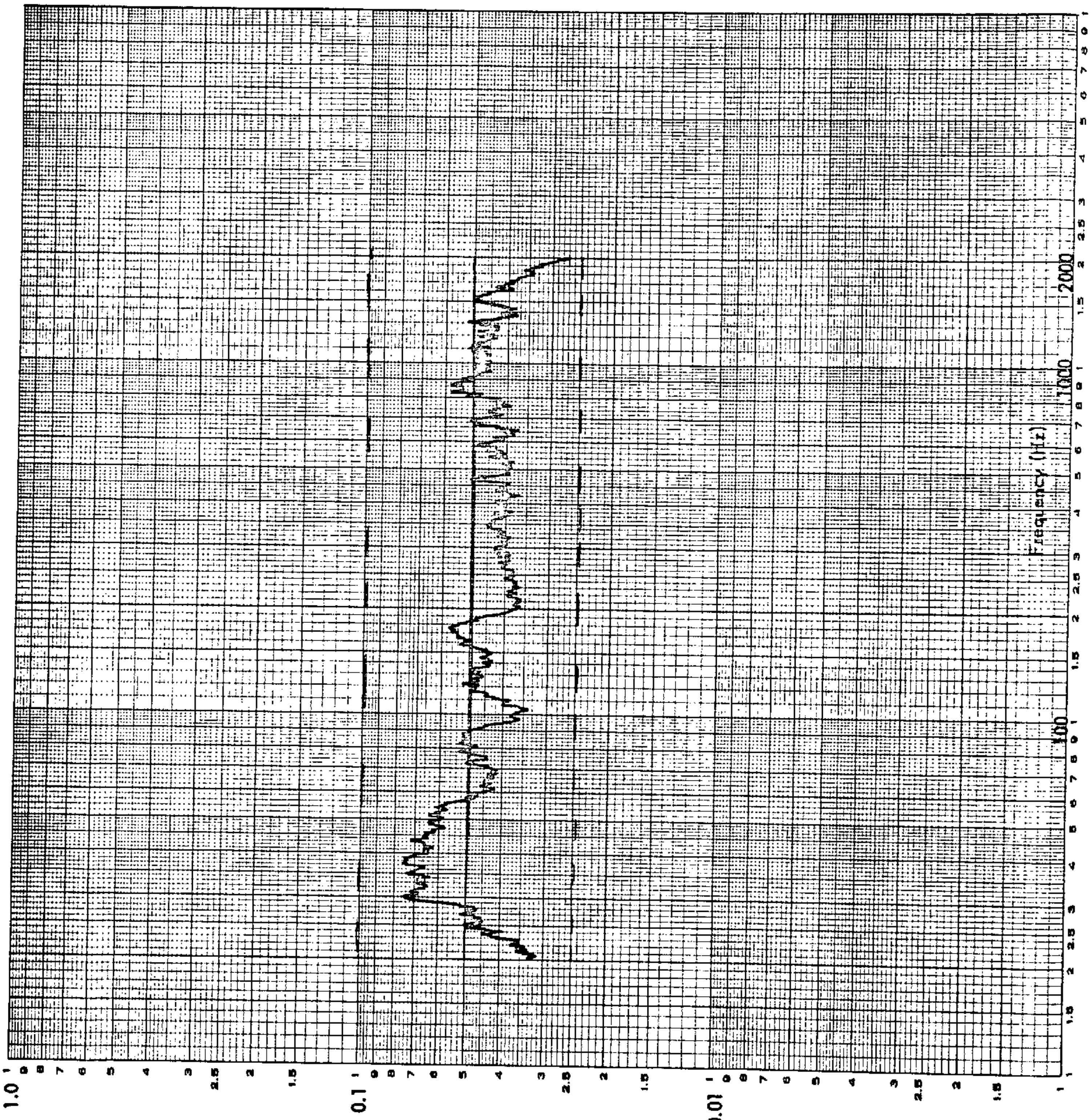
Wayne, New Jersey 07470

Burlington, Massachusetts 01803

FORM NO. 9-52 Report No. NT-7523-11 Figure ______ Page 11

RANDOM VIBRATION ANALYSIS

Job Number NT-7523 Customer Ion Physics Corp Date 9-14-70
Specimen P/N EE65-1 Specimen S/N 3 Test Temp. Room Ambient
Bw. Analyzed Filter No. 1 20 to 100 Hz, Bw. Analyzed Filter No. 2 100 to 2000 Hz
Analyzing Filter No. 1 20 Hz Analyzing Filter No. 2 50 Hz
Vibration Axis 1st & 2nd Lateral Technician R. Borghetti



Spectral Density Level X 10 - (g^2/Hz)

Associated Testing Laboratories, Inc.

Wayne, New Jersey 07470
Burlington, Massachusetts 01803

Test Report No. NT-7614-11

No. of Pages 12

Contract No.: NAS-9-10399

Report of Test on

ELECTRON GUN

Environmental Testing

for

Ion Physics Corporation

Associated Testing Laboratories, Inc.

Burlington, Massachusetts

Date October 13, 1970

	Prepared	Checked	Approved
By	E. R. Mencow	R. Borghetti	E. E. Kulcsar
Signed	E R Mencow	R. Borghetti	E. E. Kulcsar
Date	10/14/70	10-16-70	10-16-70

Surveillance by: A P Venezia QCA DCASR Boston
P.O. 08026/505
ONG NT.7123
16 Oct 70
DCRB-QOR

Administrative Data

1.0 Purpose of Test:

To evaluate the performance of the Electron Gun when subjected to Environmental Testing in accordance with the referenced Specification and Procedures of this Test Report.

2.0 Manufacturer: Ion Physics Corporation
South Bedford Street
Burlington, Massachusetts 01803

3.0 Manufacturer's Type or Model No.: EE65-1

4.0 Drawing, Specification or Exhibit: In accordance with written and verbal instructions from Ion Physics Corporation.

5.0 Quantity of Items Tested: One (1) (S/N 4)

6.0 Security Classification of Items: Unclassified

7.0 Date Test Completed: October 8, 1970

8.0 Test Conducted By: Associated Testing Laboratories, Inc.
NEW ENGLAND DIVISION

9.0 Disposition of Specimens: Returned to Ion Physics Corporation

10.0 Abstract:

The submitted Electron Gun was subjected to Sinusoidal Vibration over the frequency range of 20 to 2000 Hz at levels up to ±6g's peak. The unit was vibrated in three mutually perpendicular axes. There was one sweep up from 20 to 2000 Hz in each axis. There was no visible damage incurred to the Electron Gun as a result of the Sinusoidal Vibration Test.

10.0 Abstract (continued)

The Electron Gun was subjected to Random Frequency Vibration Testing over the range of 20 to 2000 Hz at a PSD Level of $0.05g^2/Hz$ and an overall level of 10g's rms. The unit was subjected to the Random Vibration for a period of 10 seconds in each of its 3 mutually perpendicular axes. At the conclusion of the Random Vibration Test, there was no visible damage incurred to the Electron Gun.

The Electron Gun was subjected to a Shock Test in each of its three mutually perpendicular axes. A total of 6 blows was delivered to the unit, 1 in each direction of each axis. Each shock pulse approximated a half sine wave with a peak amplitude of 15g's and 15 millisecond time duration. There was no visible damage incurred to the Electron Gun as a result of the Shock Test.

LIST OF APPARATUS

Item	Manufacturer	Model No.	Accuracy	Calibration Date	Calibration Date Due
Vibration System	Ling Electronics	A175	±2%Freq. ±5%Ampl.	7-28-70	10-28-70
Accelerometer	Endevco Corporation	2215-E	±5%	7-24-70	10-24-70
Automatic Spectral Density Equalizer/ Analyzer	Ling Electronics	ASDE-80	±5%	8-20-70	9-20-70
Analyzer Console	Associated Testing Laboratories, Inc. (New England Division)	135	±5%	10-5-70	11-5-70
Timer	Dimco-Gray Company	165	±1sec/hr.	7-13-70	1-13-71
Shock Machine	Avco Corporation	110 Model -3	N/A	Before Use	
Shock Console	Associated Testing Laboratories, Inc. (New England Division)	333	±5%	7-10-70	10-10-70
Oscilloscope	Tektronix	564	±3%	9-10-70	12-10-70

Associated Testing Laboratories, Inc.
Wayne, New Jersey 07470
Burlington, Massachusetts 01803

SINUSOIDAL VIBRATION TEST

TEST PROCEDURE

The submitted Electron Gun was subjected to a Sinusoidal Vibration Test in accordance with written and verbal instructions from a Representative of Ion Physics Corporation. The following is a description of the test as it was performed.

The Electron Gun was securely attached to its Vibration Test fixture, which was then attached to the table of the Vibrator. The Electron Gun was then subjected to Sinusoidal Vibration over the frequency range of 20 to 2000 Hz at the levels given below:

TABLE I

Frequency (Hz)	Amplitude
20 - 500	±1g
500 - 2000	±6g's

The frequency range from 20 to 500 Hz was swept up in approximately 30 seconds and the frequency range from 500 to 2000 Hz was swept up in approximately 30 seconds. There was no return sweep.

The above procedure was performed in each of the units' three mutually perpendicular axes. The Electron Gun was examined for damage after vibration in each axis.

TEST RESULTS

There was no visible damage incurred to the Electron Gun as a result of the Sinusoidal Vibration Test.

RANDOM VIBRATION TEST

TEST PROCEDURE

The Electron Gun was subjected to Random Frequency Vibration Testing in accordance with written and verbal instructions from an Engineering Representative of Ion Physics Corporation. The following is a description of the test as it was performed.

The Electron Gun was secured to the Vibrator as previously described in the Sinusoidal Vibration Test Procedure. The unit was then subjected to the following Random Vibration Test:

TEST LEVEL

Frequency (Hz)	PSD Level (g^2/Hz)
20 - 2000	0.05

Overall Level = 10g rms

The above Random Vibration Test levels were applied in each of three mutually perpendicular axes.

Prior to mounting the specimen to the Vibration Test fixture, equalization of the Random System was accomplished by means of a System containing 85 parallel band-pass filters with individual attenuators for spectrum shaping. Each filter had a maximum bandwidth of 25 Hz. The System also contained Monitoring circuits with power spectral density meters which read directly in g^2/Hz. The System was first set-up in the closed loop mode. After programming in the specified test levels, the test spectrum was applied to the shaker system. Where necessary, resetting of equalization controls was performed at those frequencies where the applied test level had deviated from that specified. The output of the Control Accelerometer with its associated normalizing filters was applied to the input of a Spectral Density Analyzer/Tracking Filter. The recorded power spectral density was displayed on an X-Y Plot. The tolerance of the displayed power

RANDOM VIBRATION TEST

TEST PROCEDURE (continued)

spectral density level was ±3db. The filters used for analyzing the random frequency test spectrum were as follows:

A. 20 Hz - from 20 to 50 Hz.

B. 50 Hz - from 50 to 2000 Hz.

After having assured that the test levels were within the stated tolerances, the System was shut-down and the Electron Gun was mounted to the test fixture.

The unit was subjected to the Test Levels for a period of 10 seconds in each of three mutually perpendicular axes.

The Electron Gun was examined for evidence of physical damage upon completion of each Random Vibration Exposure.

TEST RESULTS

There were no visible damage incurred to the Electron Gun as a result of the Random Vibration Test.

SHOCK TEST

TEST PROCEDURE

The Electron Gun was subjected to a Shock Test in accordance with written and verbal instructions from Ion Physics Corporation. The following is a description of the test as it was performed.

The Electron Gun was securely mounted to its fixture which, in turn, was mounted to the carriage of the Shock Machine. The unit was then subjected to a total of 6 blows, 1 in each direction of three mutually perpendicular axes. The magnitude of the shock pulse was 15g's, the time duration was 12 milliseconds, and the wave form was half sine wave. At the end of the test the unit was examined for external mechanical damage.

TEST RESULTS

There was no visible damage incurred to the Electron Gun as a result of the Shock Test.

RANDOM VIBRATION ANALYSIS

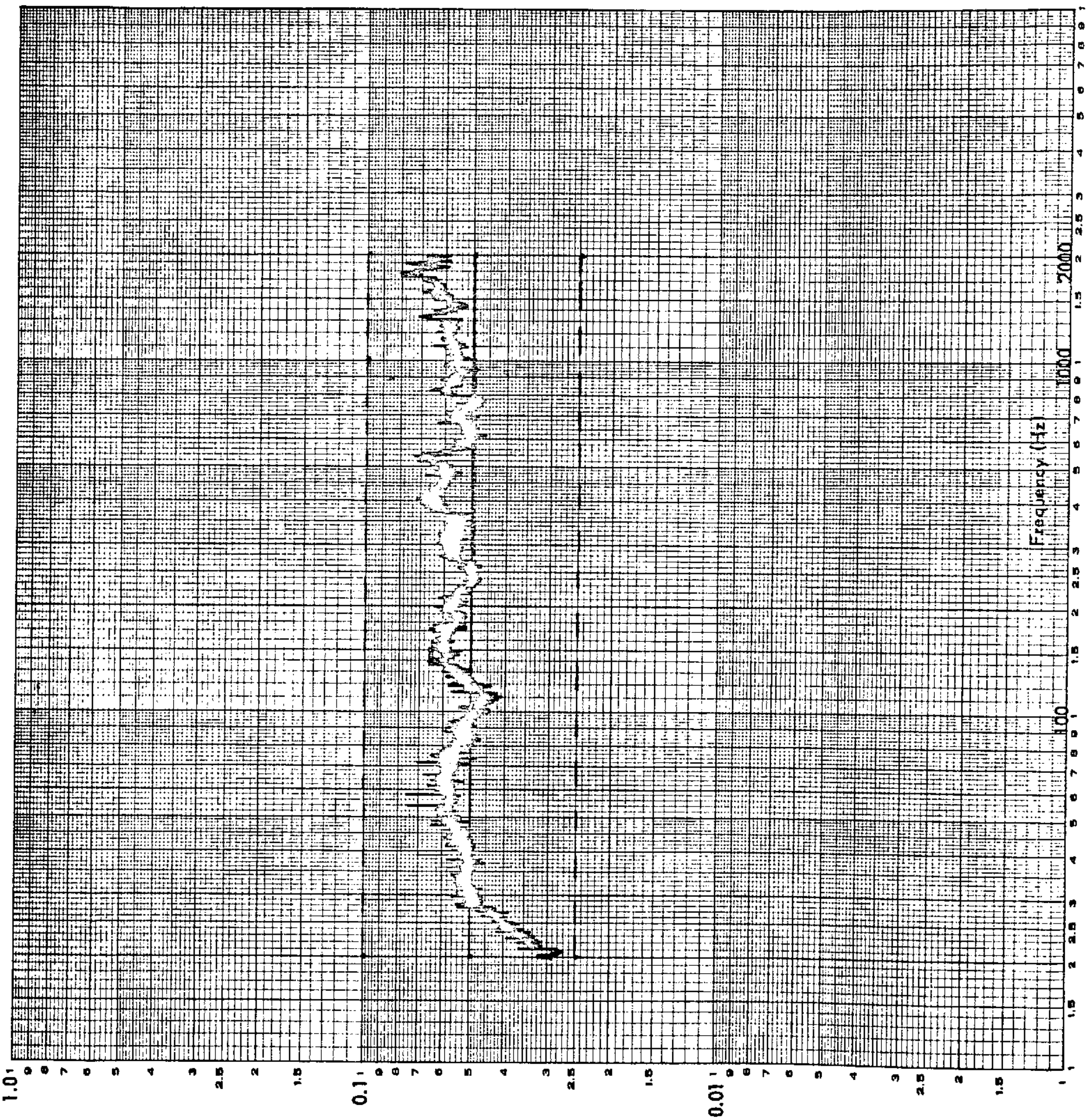
Job Number NT-7614 Customer Ion Physics Corp. Date 10-8-70

Specimen P/N EE 65-1 Specimen S/N 4 Test Temp. Room Ambient

Bw. Analyzed Filter No. 1 20 to 50 Hz, Bw. Analyzed Filter No. 2 50 to 2000 Hz

Analyzing Filter No. 1 20 Hz Analyzing Filter No. 2 50 Hz

Vibration Axis Vertical (longitudinal) Technician R. Borghetti



Spectral Density Level X 10 - (g^2/Hz)

Associated Testing Laboratories, Inc.

Wayne, New Jersey 07470

Burlington, Massachusetts 01803

FORM NO. 9-52 Report No. NT-7614-11 Figure ______ Page 8

RANDOM VIBRATION ANALYSIS

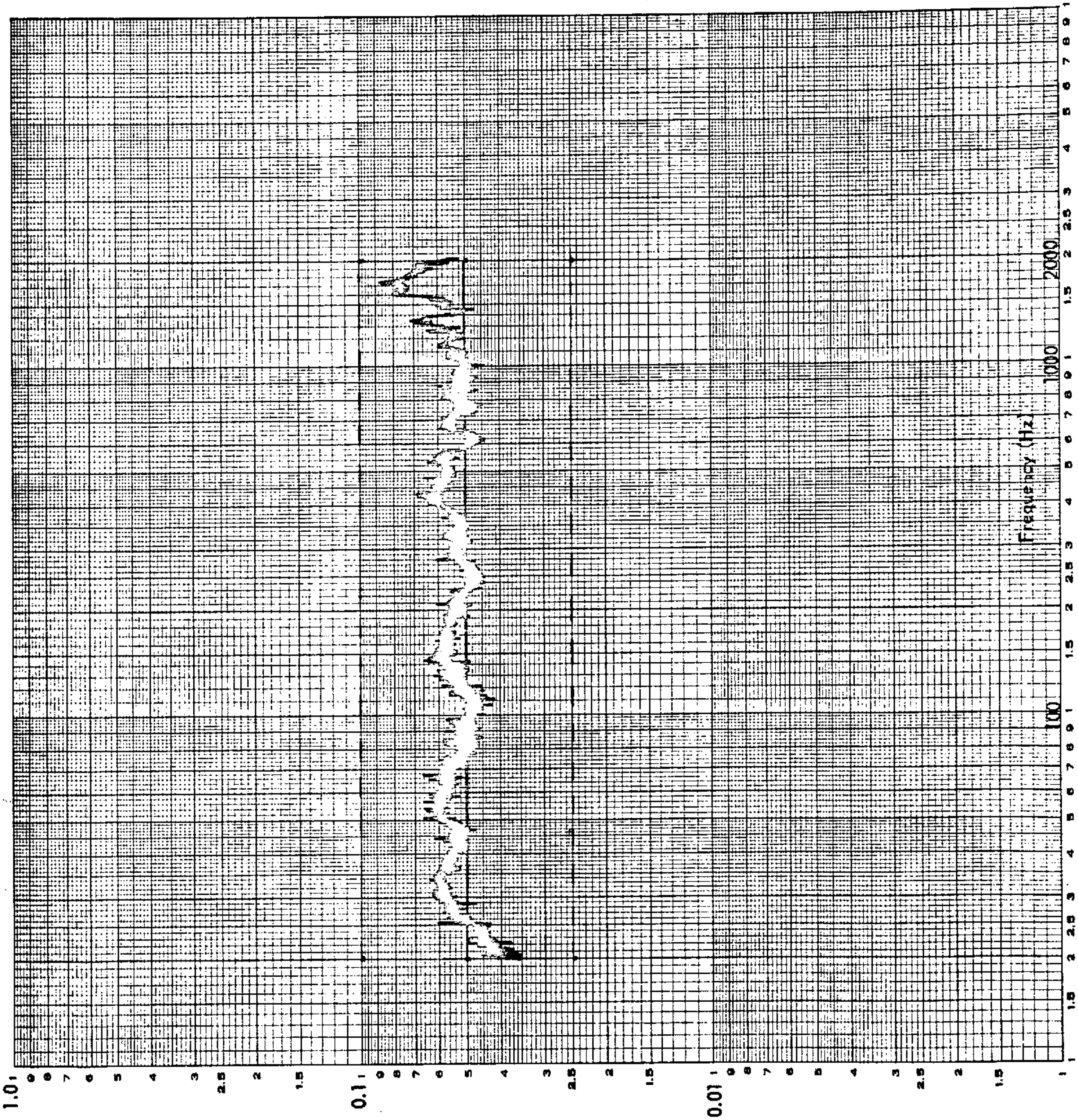
Job Number NT-7614 Customer Ion Physics Corp. Date 10-8-70

Specimen P/N EE65-1 Specimen S/N 4 Test Temp. Room Ambient

Bw. Analyzed Filter No. 1 20 to 50 Hz, Bw. Analyzed Filter No. 2 50 to 2000 Hz

Analyzing Filter No. 1 20 Hz Analyzing Filter No. 2 50 Hz

Vibration Axis 1st & 2nd Lateral Technician R. Borghetti



Spectral Density Level X 10 - (g^2/Hz)

Associated Testing Laboratories, Inc.

Wayne, New Jersey 07470

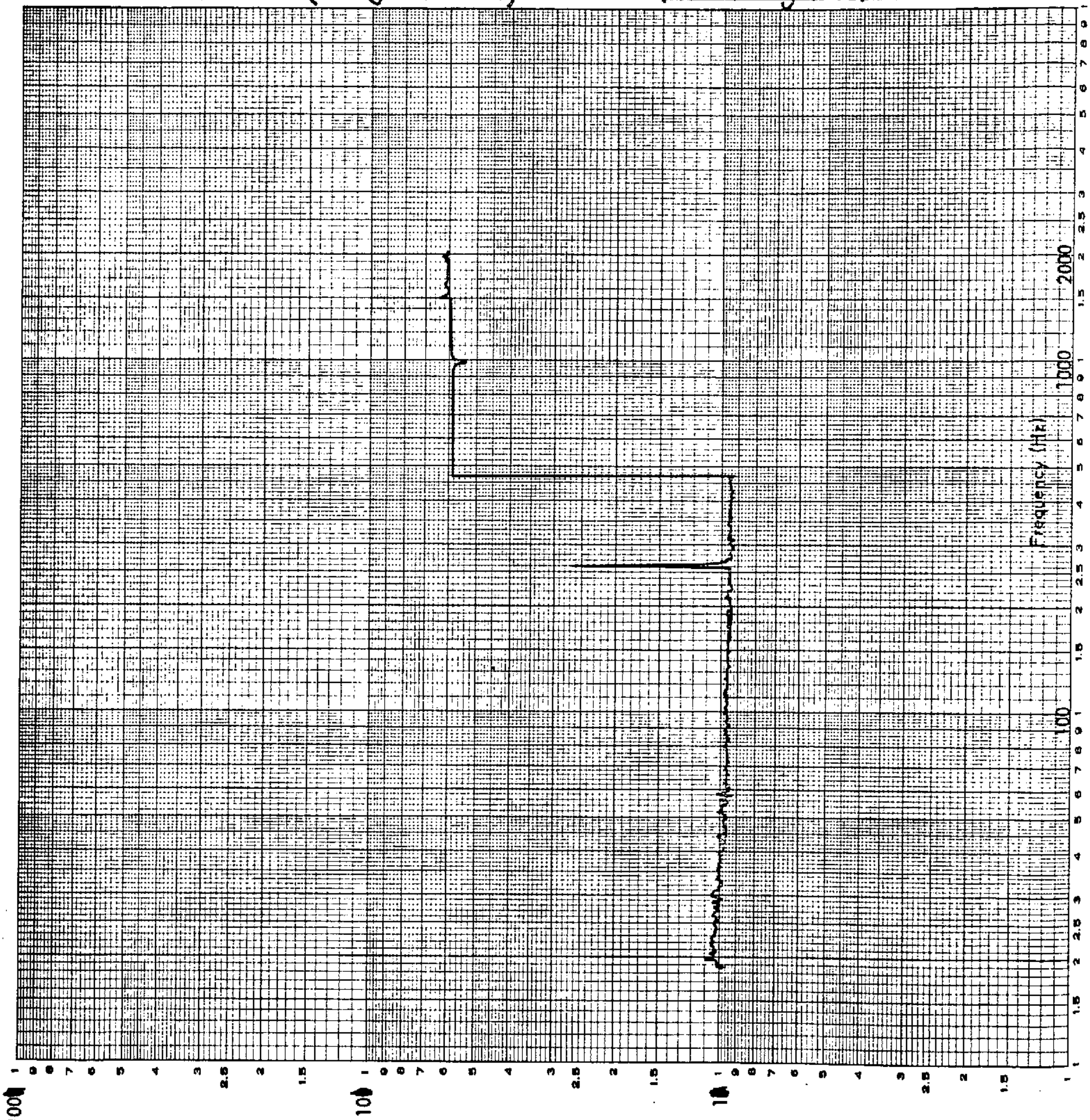
Burlington, Massachusetts 01803

SINUSOIDAL VIBRATION ANALYSIS

Job Number NT-7614 Customer Ion Physics Corporation Date 10-8-70

Specimen P/N EE65-1 Specimen S/N 4 Test Temp. Room Ambient

Axis Vertical (longitudinal) Technician R. Borghetti



Associated Testing Laboratories, Inc.

Wayne, New Jersey 07470

Burlington, Massachusetts 01803

FORM NO. 9-51

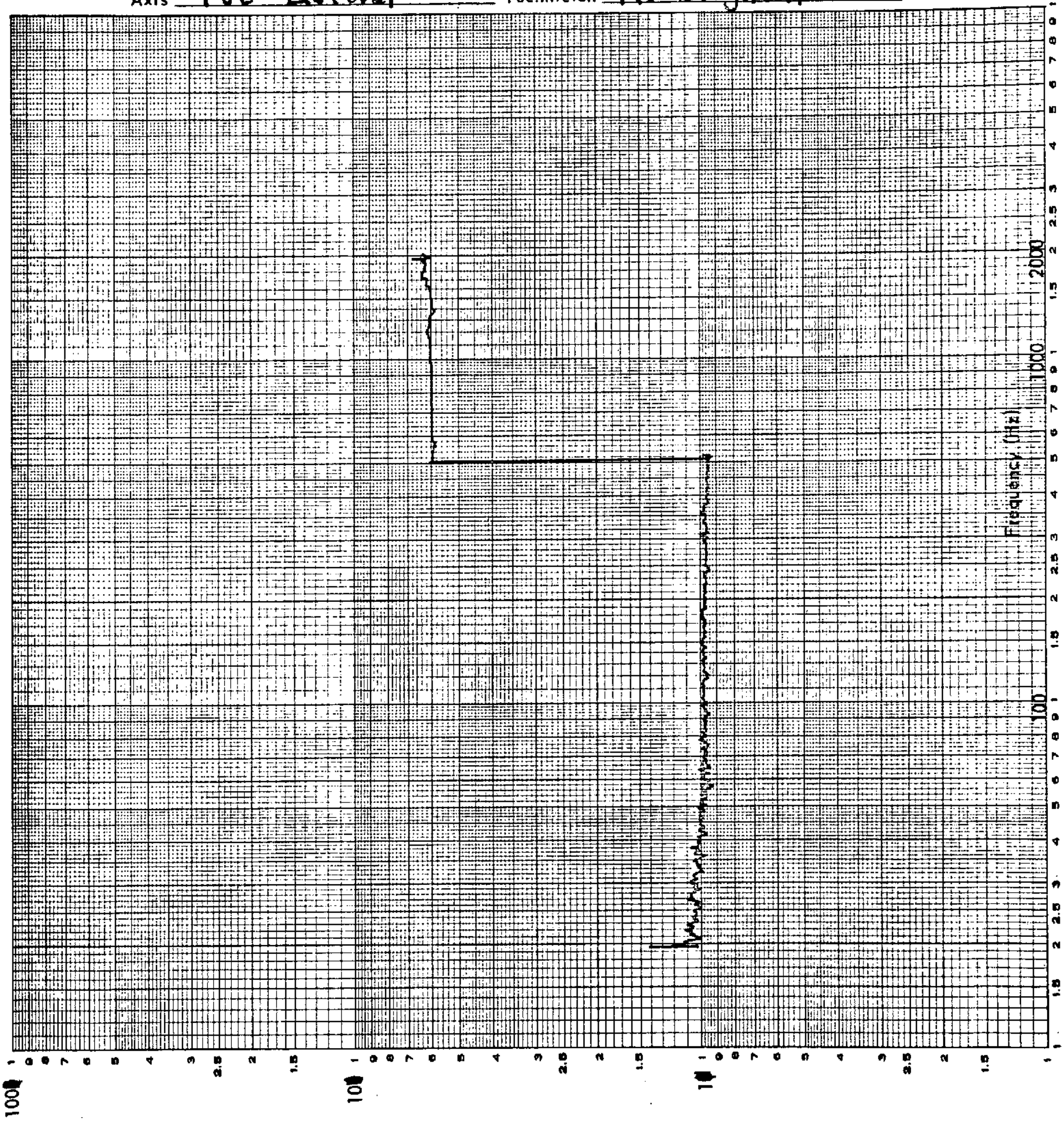
Report No. NT-7614-11 Figure ______ Page 10

SINUSOIDAL VIBRATION ANALYSIS

Job Number NT-7614 Customer Ion Physics Corporation Date 10-8-70

Specimen P/N EE65-1 Specimen S/N 4 Test Temp. Room Ambient

Axis 1st Lateral Technician R. Borghetti



"g" Level

Associated Testing Laboratories, Inc.

Wayne, New Jersey 07470

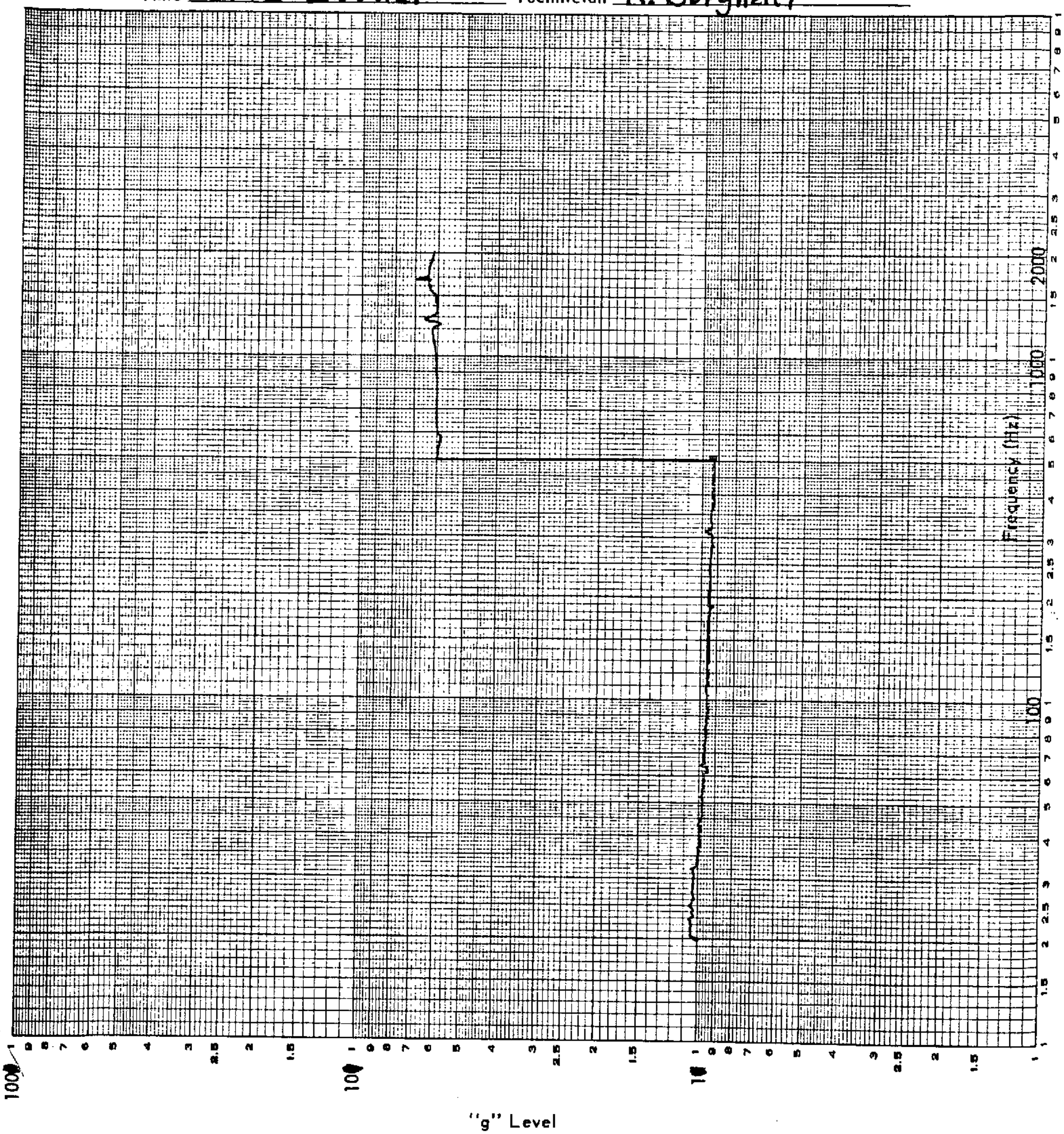
Burlington, Massachusetts 01803

SINUSOIDAL VIBRATION ANALYSIS

Job Number NT-7614 Customer Ion Physics Corporation Date 10-8-70

Specimen P/N EE65-1 Specimen S/N 4 Test Temp. Room Ambient

Axis 2nd Lateral Technician R. Borghetti



Associated Testing Laboratories, Inc.

Wayne, New Jersey 07470

Burlington, Massachusetts 01803

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